IOWA

GEOLOGICAL SURVEY

VOLUME IV.

THIRD ANNUAL REPORT, 1894,

WITH

ACCOMPANYING PAPERS.

GEOLOGICAL CORPS:

Samuel Calvin, A. M., Ph. D., State Geologist.
Charles Rollin Keyes, A. M. Ph. D., Assistant State Geologist.
G. E. Patrick, A. M., Chemist.

DES MOINES:
PUBLISHED FOR THE IOWA GEOLOGICAL SURVEY.
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1895.

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C. H. Gordon .... Local Geology
F. M. Fultz .... Local Geology
A. G. Wilson .... Local Geology

Nellie E. Newman .... Secretary
F. C. Tate .... Draughtsman

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THIRD ANNUAL

Report of the State Geologist.

IOWA GEOLOGICAL SURVEY,
DES MOINES, December 31, 1894.

To Governor Frank D. Jackson and Members of the Geological Board:

GENTLEMEN:—I have the honor to submit, in accordance with law, an account of the work done by the Iowa Geological Survey during the past year. The work of 1894, was to a large extent, simply a continuation of that begun in 1893. So far as possible, investigations entered upon by persons employed on the survey during the preceding year were continued in 1894, but owing to the limited means at the disposal of the Survey it became necessary early in the season to suspend all work that could be temporarily laid aside without serious loss. It is very gratifying, however, to be able to report that notwithstanding the rather narrow means available for its prosecution, the work of the Survey has been pushed with vigor along certain lines, and substantial results have been attained.

In addition to the attention necessarily given to administration, to correspondence, and to answering inquiries of all imaginable kinds, my own work has included the finishing of the report on Allamakee county, which report is now ready, with suitable illustrations, for the printer; the investigation of the composition and origin of Iowa chalk, and the preparation

of a report which was contributed to Volume III; the preparation of newspaper articles giving information of immediate interest to certain localities; and the contribution of papers to scientific periodicals and learned associations.

My work in the field included the investigation of Delaware county, with a view to making a complete report on its geological structure, and geological products of economic importance. Progress was made with the field work of Buchanan, Fayette, Howard, Winneshiek and Dubuque counties. Jones county was nearly completed last year, but it seemed best to defer further work on it until some of the problems in counties adjacent can be investigated. It is often the case that the geology of any given county cannot be clearly elucidated in all its relations and details without following the different formations into the counties adjoining. While many of the investigations so made are not available in writing up the report on the county under immediate consideration, they all have the effect of simplifying and expediting the work when the several counties thus partially studied are taken up in detail.

I have also given a considerable share of time to work on the collections, particularly on those representing the paleontology of the several formations in northeastern Iowa. Paleontology furnishes the key to the correct identification of the several beds as we pass from one rock exposure to another; for in a drift-covered region like Iowa exposures are not continuous, and the geologist must avail himself of the only known reliable means for recognizing at separated localities strata of the same geological horizon. The thickness of deposits of commercial importance, and their geological extent, can often only be determined by the most careful attention to paleontological data. A large series of specimens has been identified and prepared for display in the cases of the museum.

The work of Dr. Charles R. Keyes on the coal, gypsum and other economic products of Iowa, as well as on certain counties of the state, is set forth in detail in his administrative report, herewith submitted.

Since the resignation of Dr. Keyes in order that he might assume the duties of State Geologist of Missouri, Mr. H. F. Bain

has been appointed chief assistant. Mr. Bain has rendered very efficient service in connection with all work assigned him, and for a full statement of what he has personally accomplished during the year attention is respectfully directed to his administrative report, which is here appended.

Prof. G. E. Patrick began an investigation of the soils of the state, analyses being made of the best and the poorest soil in each of the sections covered by his investigations, the effort being to determine whether it was possible to discover from the chemical properties what was the controlling factor in determining the difference in the value of the soil. A considerable number of these analyses had been made, and were pointing to important results when the work had to be suspended. Prof. Patrick has also made analyses of coals and of the ores of iron, lead and zinc. The calorimeter tests of the coals, which it was hoped might be taken up this year, it has been necessary to postpone. The coal samples have, however, been preserved, and will be available for such work at any time in the future.

Mr. E. H. Lonsdale has had the clays in charge. Half of the field work was completed the previous season, and the remainder was done during the past year. A report on the clay industries of the state is now being prepared by him, and is well advanced towards completion.

Mr. A. C. Spencer continued the work on building materials, begun the previous year, intending to make a complete study of the limes and cements of the state. This work was continued up to the last of May, a considerable amount of valuable information being accumulated, when the necessities of the decreased appropriation forced the discontinuance of the work.

Mr. A. G. Leonard continued his work on the zinc and lead deposits of northeastern Iowa, completing in May the field work. He has submitted his report which is now being prepared for the printer. In order to make this report most valuable it will be necessary to have a map of the region to accompany it. It is hoped that such a map may be made during the early part of the coming season.

Mr. C. H. Gordon has completed and handed in his manuscript of the Geology of Van Buren county, and also a paper on

Buried River Channels in southeastern Iowa. The paper on Van Buren county will constitute a part of this volume. That on Buried River Channels appears in the second annual, Volume III.

Prof. Wm. H. Norton has made a study of the deep wells of northeastern Iowa, with special reference to determining the thickness and extent of the various geological formations. Much valuable information was obtained and the results of his work are incorporated in a report which forms one of the chapters of Volume III. Professor Norton has also finished the field work on Linn county, and his full report on this work has been submitted and is being prepared for the printer.

Prof. S. W. Beyer spent a number of weeks during the summer in field work, devoting attention to the geology of Boone county, and to geological problems in the northwestern part of the state.

Owing to the press of other work Mr. Beyer found himself unable to devote that amount of time to the subject of artesian waters which seemed desirable in order to allow the early completion of the volume. During the year, therefore, this work has been placed in the hands of Professor Norton, who had already paid considerable attention to this subject. For the present Mr. Beyer will devote what time he may be able to give to survey work to areal geology. His report on Boone county will probably be completed within the next year.

Mr. A. J. Jones finished some previously incompleted work in Van Buren county and Professor A. G. B. Wilson rendered valuable assistance on the field work of Delaware county.

Mr. F. C. Tate continued in charge of the drafting up to October 1st, and Miss Nellie E. Newman continued her work as secretary up to October 15th.

Since the date last mentioned the working force of the Survey has been practically limited to the chief geologist, the assistant geologist and the chemist.

Necessarily the first work following the organization of a State Survey must be preliminary and in the nature of a general reconnoissance of the whole field. A considerable amount of the work of the past seasons was of this preliminary nature.

A knowledge of the general characteristics, subdivisions and geographic distribution of the geological formations is indispensable to good areal work, so that the work in one region may be checked and correlated properly with that in every other. This work is now largely accomplished and the Survey is ready to take up areal investigations and push them as rapidly as the means available will permit.

There are differences of opinion among working geologists as to what the areal unit for purposes of detailed investigation should be. The subdivision of the state into counties is wholly artificial, and hence the county boundaries have no relation whatever to the distribution of geological formations. Nevertheless it seems to me best in prosecuting a State Survey to adopt the county as the areal unit. The boundaries of counties are definitely located and generally known. The county is one of the organic units of civil government. Its inhabitants are bound together by common purposes, and have a common pride in its resources and in whatever promotes its welfare. Definite information regarding the resources of his county as such, has more interest to the ordinary intelligent citizen, thoroughly loyal to his own locality as he usually is, than a report on an area embracing probably parts of several counties, though that area lend itself more naturally to scientific investigation because limited by natural geographic features or distinguished by some peculiarities of geologic structure. The adoption of the county as the areal unit, will not add anything to the amount of field work to be done. Its only disadvantage, so far as I can see, lies in the fact that it will increase slightly the volume of the reports, because each county must be written up fully and independently. The advantages of the plan are so many as to far outweigh any slight disadvantages. The present citizens, as well as prospective settlers and investors, think not of naturally defined areas, but of counties in which they become interested; and they will turn to the geological report of the several counties under consideration for information concerning their resources. Under each county, therefore, the information should be the fullest and most trustworthy possible; discussing the geological structure, the supply of building

stones, limes and cements, the character and quantity of clays and the uses to which they are adapted, the nature and origin of the soils, the water supply, both in superficial and underground streams, the mineral products such as coal, lead, zinc, iron, gypsum, and the like, the supply of road materials; in short, whatever may be necessary to give parties interested a clear conception of the future industries that the county will probably support.

The completion of the work by counties will be the end to which the energies of the Survey will be chiefly directed in the future. Reports on a few of these regions appear in Volume III, and Volume IV, the manuscript for which is herewith submitted, is wholly devoted to county geology. A special report on the clays of Iowa is about ready to be submitted for your approval, but the special reports on building stones, limes and some other subjects can be written more economically when work on the several counties is finished.

During the year the publication of the work on coal, prepared by Dr. C. R. Keyes, and constituting Volume II of the Survey reports, has been completed, and partially distributed as the law requires. The second annual report, Volume III, is about ready for distribution; the manuscript and illustrations for the third annual report, Volume IV, are herewith submitted.

In submitting this report containing the reports on the geology of several counties, there are a few general considerations to which it might perhaps be well to call attention.

Iowa, as is well known, is a drift covered region. It has been but little disturbed by orographic movements, and the principal changes which have taken place in the strata since deposition are due to erosion. These geological conditions control the methods applicable to mapping it. Owing to the thick mantle of drift it is often impossible to map with any acceptable degree of accuracy, the minor divisions of the geological formations.

Often the division lines between two contiguous formations can only be drawn approximately, and in a straight rather than curved line such as actually exists. This will explain an

appearance on the maps which might easily be mistaken for fault lines. When the conditions present have permitted the tracing of the actual contact line it has been done and is shown on the maps. When the line is only approximate the fact may be readily recognized from the manner in which it is drawn.

In tracing the eastern limit of the coal measures it has not always been possible to mark the exact division line between the productive and the unproductive portions of the Carboniferous. In such case the areas mapped as coal measures indicate only those in which coal is known to occur, or in which the indications are sufficient to warrant prospecting with the drill. It must be remembered that within these areas smaller areas over which the coal measures have been removed by erosion are not unlikely to occur. Since, however, the data do not exist by which they can not be mapped, and never will all exist until the coal field is exhausted, they can not be separated. It is also true that there are probably numerous small outliers as yet undiscovered lying beneath the drift. Some of these may in time prove productive.

It is gratifying to be able to state that the work of the Survey continues to demonstrate that the Iowa coal measures are far richer than they have been believed to be, and it is not improbable that when the peculiar conditions of their deposition and preservation are fully understood, we may have the same degree of certainty in regard to the presence or absence of coal in a particular region which now obtains in other fields.

In drawing and printing these maps the Survey has been able to effect a saving of fully 40 per cent in the usual cost of such work. They were carefully drawn, and the lettering put in from type rather than by hand. In this way the cost of the original drawing was greatly reduced, and a map prepared with sufficient detail to allow it to be reproduced directly by photo-lithographing, doing away with the necessity of an engraving on stone, and effecting very considerable reduction in cost. It is believed that the results obtained are fully up to the standard required for such work.

The original base map used in the field has been in a majority of cases taken from some county atlas, and was usually on a

scale of two inches to the mile. This has been corrected and revised, both from the county records and the field notes of the geologist in charge. On it has been marked the exact location of each known outcrop, with references to note book and page where the outcrop is described in full. From this foundation the base map used was drawn on a scale of $\frac{3}{4}$ inch to the mile, which in reproducing was further reduced to $\frac{1}{2}$ inch to the mile. Upon this smaller map the colors representing the different formations were laid down.

In the color scheme that adopted by the International Congress of Geologists has been followed in general, though modifications have been introduced. When the minor divisions of a formation are sufficiently well shown to be mapped separately they are shown by the pattern lines. Where these minor divisions cannot be separated, a solid color representing the major division is used. In this way each county map has represented on it all the detail which the conditions there allow, and yet the several counties show a general agreement.

In those counties where the paleontological work has not as yet been carried on so as to separate the divisions of the different formations on that basis, the lithological and stratigraphical units of the county have been mapped as such, it being intended to introduce as much detail of this character on the maps as will admit of such expression, and as appears to be of probable usefulness in that connection. Additional details are given in the text accompanying each report.

It is believed that the plan adopted embraces that degree of flexibility which is advisable and which will meet the conditions of the various regions as the work of the Survey advances.

Respectfully,

SAMUEL CALVIN,
State Geologist.

REPORT OF DR. CHARLES R. KEYES.

IOWA GEOLOGICAL SURVEY,
DES MOINES, December 31, 1894.

SIR:—I have the honor of transmitting to you an account of the work conducted by me during the past year.

During the first weeks of 1894 all efforts were directed to getting through the press the report on the Coal Deposits of Iowa, which forms Volume II of the series issued by the Survey. At the same time, and until after the field season had opened, the work of editing Volume III and of supervising the printing of the first half, occupied considerable time. The necessary field work to finish up the report on two counties was also accomplished. The work on the gypsum deposits begun two years ago, was completed and the report written. Mr. Lonsdale finished up the topographical map of the region commenced some time previously by Mr. Hess. The reports on personal work completed during the year are:

1. "Coal Deposits of Iowa," forming Volume II. It is a description of the salient geological features of the coal region, with particular reference to the coal-bearing strata, the nature of coal horizons, and a detailed account of the coal beds as exhibited in the different parts of the Iowa field.

2. "Administrative Report of the Assistant State Geologist for 1894."

3. "Work and Scope of the Geological Survey," is an account of what has been done by the Survey since its organization. It was prepared primarily for the use of the legislators and the newspapers of the state.

4. "Glacial Scorings in Iowa." Heretofore only a few isolated evidences of ice scratches were known. Recently a number of new localities, showing fine glaciation, were discovered, and special attention is here called to them.

5. "Economic Geology of Lee County," which contains a report on the natural resources of the district. It is accompanied by a colored geological map of the area, on a scale of one-half inch to the mile, and a number of suitable illustrations.

6. "Economic Geology of Des Moines County," a report on the geology and natural resources of Des Moines county, similar to the report on Lee county.

7. The inquiry in regard to the Sioux quartzite, begun last year, was continued. Mr. Beyer also spent some time in the region, and the results of his work will probably be ready in time for insertion in the current annual report.

The work on Building Stones was reviewed and considerable information obtained.

Respectfully,

CHARLES R. KEYES,
Assistant State Geologist.

To PROF. SAMUEL CALVIN, State Geologist.

REPORT OF MR. H. F. BAIN.

IOWA GEOLOGICAL SURVEY,
DES MOINES, December 31, 1894.

SIR:—I submit herewith a statement of the work done by me during the year just past.

The greater portion of the months of January and February was spent in the office assisting in the revision of the manuscript and the reading of the proof of Volume II and the first portion of Volume III, which were at that time going through the press. Time was found in the first of the two months mentioned to take a trip down the Des Moines river through Marion, Mahaska and Wapello counties for the purpose of connecting the work done by Messrs. Keyes and Gordon.

March 6th I left Des Moines for Plymouth county to investigate reported discoveries of valuable lignite which were at that time attracting attention. While in the region I did additional work on the Cretaceous of the Sioux valley the results in part appearing in Volume III of the Survey reports.

In the early part of April I took up the work in Keokuk county, extending it later into Mahaska and Washington counties, and continuing the work until September 1st. The month of September was spent in Woodbury and neighboring counties. At the first of October I was called to Des Moines and placed in charge of the office where I have since been.

During the year I have completed the following work:

(1) Geology of Mahaska county.
(2) Geology of Washington county.
(3) Geology of Keokuk county.

These reports are now copied and ready for illustrating and final revision. In addition I have in preparation:

(1) Geology of Woodbury county.

(2) Report on the Methods of Coal Mining in Iowa as Influenced by Geological Structure.

It is expected that the former of these papers will be practically completed at some time during this winter and the second will be pushed as rapidly as circumstances permit. I have also spent some time, and expect to spend more, in an investigation of the mining problems of Polk county in view of a joint report on the geology of the county by Dr. Keyes and myself.

In addition to the above work several short articles have been furnished for newspapers and geological journals and a considerable amount of manuscript revised.

H. FOSTER BAIN,
Assistant Geologist.

TO PROFESSOR SAMUEL CALVIN, State Geologist.

REPORT OF PROF. G. E. PATRICK.

IOWA AGRICULTURAL COLLEGE,
AMES, IOWA, December 31, 1894.

DEAR SIR:—I have the honor of presenting to you the following report of the work done by the chemical division of the Survey during the year ending December 31, 1894.

The samples analyzed during the year are as described below. All except the soil samples were sent me from the office of the Survey, at Des Moines; the soil samples were sent me direct by persons collecting them.

SAMPLE NUMBER.	DESCRIPTION.
261	Cerussite (lead carbonate) Buena Vista, Clayton county.
262	Smithsonite (zinc carbonate) Durango, Dubuque county.
263	Smithsonite (zinc carbonate) McGovern mine, Dubuque county.
264	Galena (lead sulphide) Lansing, Allamakee county.
265	Galena (lead sulphide) Kerrick mine, Dubuque county.
266	Smithsonite (zinc carbonate) Treub & Southwell mine, Dubuque.
267	Clay (blue) Mason City, Cerro Gordo county.
268	Clay (dark gray) Indianola, Warren county.
269	Clay (buff) Indianola, Warren county.
270	Clay (yellow) Spencer, Clay county.
271	Clay, Red Oak, Montgomery county.
272	Clay (alluvial) Bridgewater.
273	Clay (loess) Guthrie Center, Guthrie county.
274	Galena (lead sulphide) Bear Creek, Allamakee county.
275	Iron ore (limonite) Iron Hill, Allamakee county.
276	Smithsonite (zinc carbonate) Mineral Creek, Allamakee county.
277	Lead carbonate and sulphide, Mineral Creek, Allamakee county.
278	Iron Ore (haematite) Waukon, Allamakee county.
279	Iron Ore (limonite) Waukon, Allamakee county.
280	Clay, Crills Mill, Plymouth county.
281	Gypsum, Iowa Plaster Co., Quarry No. 1, Fort Dodge, Webster county.
282	Gypsum (white selected), Iowa Plaster Co., Fort Dodge, Webster Co.

283 Gypsum, Iowa Plaster Co., Quarry No. 3, Fort Dodge, Webster county.
283 B Gypsum, Iowa Plaster Co., Quarry No. 3, Fort Dodge, Webster county.
284 Gypsum, Iowa Plaster Co., Quarry No. 3, Fort Dodge, Webster county.
285 Cone-in-cone, Duncombe Mill, Fort Dodge, Webster county.
286 Cone-in-cone, Madrid, Boone county.

Soils not numbered:

2 samples from J. O. Overholt, Havelock, Pocahontas county.
2 samples from H. A. Saunders, Grand Junction, Greene county.
2 samples from John Klein, Keota, Keokuk county.
2 samples from L. Skeels, Wallingford, Emmet county.
2 samples from C. D. Miller, Denison, Crawford county.
2 samples from J. F. Grawe, Waverly, Bremer county.
2 samples from George Gadbois, Salix, Woodbury county.
2 samples from James Sullivan, Stuart, Guthrie county.
2 samples from Fred Divelbess, Logan, Harrison county.

Reports upon the analysis of all the above described samples have been made to the Assistant State Geologist, and will doubtless appear in the scientific papers of this or subsequent volumes.

SOIL INVESTIGATIONS.

A few remarks under this head seem called for. In my last annual report, dated December 29, 1893, I stated that fifty-eight samples of soil had been collected from twenty-six different counties of the state, and that their chemical examination was just being begun. This work, executed under my constant guidance and supervision, had been under way only a few months—until the latter part of April, 1894—when it was suddenly called to a halt, for lack of funds, and has not been resumed since.

It is a great pity this work had to be suspended, when only fairly begun, for it promised results of general interest and value. The objects in view were, first, to ascertain the composition of the soil in the various parts of the state, by complete quantitative analysis; second, to ascertain the proportions of the various plant-food elements existing in a condition of ready availability to plants (so far as this can be done by chemical means) in the soil of the various parts of the state; and third, to ascertain, if possible, the special causes of infertility of soils in particular localities, and to prescribe remedies therefor

wherever they might be indicated. Toward the first of these objects a good start has been made, and in the direction of the third I had gone so far as to receive, from farmers, a few samples of infertile soils for examination, when the entire work was suspended.

It is to be hoped that this work will be resumed in the near future. The farmers of the state are much interested in it, as I have good reason to believe; it promises results of real value as well as of general and scientific interest, and unless continued the beginning already made will be of comparatively little value.

Thanks are due and are hereby expressed, to the farmers who kindly gave their services in collecting the soil samples. Following are the names of those who have sent samples since the date of my last annual report:

Mr. J. H. Gerholdt, Cedar Falls, Black Hawk county.
Mr. John B. Ennis, Ottumwa, Wapello county.
Mr. T. J. Boyland, Manchester, Delaware county.
Mr. E. S. Brown, Hoskins, Woodbury county.
Mr. W. J. Thompson, Jamaica, Guthrie county.

Respectfully submitted,

G. E. Patrick,
Chemist.

To Professor Samuel Calvin, State Geologist.

GEOLOGY OF ALLAMAKEE COUNTY.

BY

SAMUEL CALVIN.

GEOLOGY OF ALLAMAKEE COUNTY.

BY SAMUEL CALVIN.

CONTENTS.

INTRODUCTION.

SITUATION AND AREA.

Allamakee county has the distinction of occupying the extreme northeastern corner of Iowa. Its eastern boundary follows the sinuous channel of the Mississippi river. On the north the county joins Minnesota, and the bounding line coincides with the parallel of 43 degrees and 30 minutes, north latitude, as located by the United States engineers and marked by monuments in 1849. The adjoining counties in Iowa are Winneshiek on the west, and Clayton on the south.

Allamakee county includes fifteen complete congressional townships, and fractions of several others that are incomplete on account of the meandering of the Mississippi river along the eastern border. Although there are five tiers of townships, numbered from 96 N. to 100 N. inclusive, the length of the county from north to south is but little more than twenty-nine miles. In making the government surveys the north line of the tier of townships numbered 100 N., was made to coincide with the northern boundary of the state, the parallel of 43 degrees and 30 minutes. It so comes about, therefore, that sections 1 to 6 in each of these townships measures only a small fraction of a mile from north to south, the actual dimensions in this direction being only about eleven rods in place of the standard three hundred and twenty. The total area included within the boundaries of the county is approximately six hundred and fifty square miles and is divided into eighteen civil townships.

PREVIOUS GEOLOGICAL WORK.

The earliest geological investigations that embraced any portion of Allamakee county were conducted under the direction of Dr. David Dale Owen. In the autumn of the year 1839, Dr. Owen, with a large party of assistants, explored the mineral lands of Iowa, Wisconsin and Illinois, but the work of the party did not on this occasion include any territory north of the mouth of the Wisconsin river. No portion of Allamakee, therefore, fell under the observation of the geologist until about ten

years later, when the work of Owen and his assistants was extended northward to the national boundary, and covered portions of Minnesota, Wisconsin, Iowa, Illinois, Missouri and Nebraska. In his report to the Commissioner of the General Land Office, published in 1852, Dr. Owen mentions the finding of lead at some points between the mouth of the Yellow river and the upper Iowa, while the picturesque features of the valley of the latter stream are charmingly set forth in connection with the discussion of the Lower Magnesian Limestone*.

To Dr. B. F. Shumard, one of the heads of sub-corps on Owen's Survey in 1848 and 1849, was assigned the task of examining the geological structure of the region north of the mouth of the Wisconsin, and in his report there are many references to points lying within the limits of Allamakee county. Sections showing the thickness of the formations exposed at Lansing, Painted Rock, the mouth of Village creek, and the mouth of Yellow River, according well with the results of more recent and more accurate measurements, are given on the plate marked Section No. 3, S†.

The next investigator to enter this territory was Professor James Hall, who as State Geologist of Iowa, made a reconnoissance along the Mississippi river from the northern boundary of the state to Keokuk, in the autumn of 1855. In the portion of his report devoted to the general geology of Iowa, Professor Hall makes a few incidental references to points in Allamakee county‡. These references occur in connection with the discussion of the formations from the Potsdam (Saint Croix) to the Trenton inclusive.

In the same volume Professor Whitney has a report on Allamakee county occupying about three pages, while in the portion of the volume devoted to economic geology there are references to mining operations on Mineral Creek§.

In the report of Dr. C. A. White, on the geology of Iowa, there are some scattered references to Allamakee county in the

* Report of a Geol. Surv. of Wis., Iowa and Minn, by David Dale Owen. pp. 63. 65 and 66.

†Ibid. See also pp. 502-504 of same volume.

‡Report on the Geol Sur. of Iowa, Prof James Hall, State Geologist, and J. D. Whitney, chemist and mineralogist, Vol. I. Part 1, 1858, p. 47, et seq.

§Ibid., pp. 317-320, and p. 460.

chapter on general geology, the most direct relating to mining operations near New Galena*.

Allamakee county is included in the driftless area of the Upper Mississippi valley, described by Chamberlin and Salisbury†, and it also falls within the region so fully discussed by McGee in his memoir on the Pleistocene history of northeastern Iowa‡. In this memoir there are frequent references to geological phenomena exhibited within the limits of the county under consideration. No detailed account, however, such as would meet the requirements of a reasonably complete geological survey, has heretofore been attempted.

PHYSIOGRAPHY.

TOPOGRAPHY.

The topography of Allamakee county presents some striking differences from the general surface configuration that prevails over the greater part of Iowa and adjacent states. These differences arise from the fact that this county lies within the driftless area of the upper Mississippi valley, while nearly all the rest of the state belongs to the region that has been deeply covered with glacial drift. Within the driftless area the topographic forms are the result of solution and mechanical erosion, acting on beds of limestone, shale and sandstone, during all the ages that have elapsed since the region was elevated above sea level. It is true that the peculiarities of topography that now characterize the driftless portion of Iowa once characterized, to a greater or less extent, the entire surface of the state. But in comparatively recent times, geologically speaking, the deeply scarred and furrowed surface that resulted from long exposure to the agents of erosion, was profoundly modified, except in the driftless area; and its ancient topography was completely obscured by a mantle of glacial detritus. The drift is simply morainic material, worn from rock ledges and spread out by the

*Rept on the Geol. Sur. of the State of Iowa, etc., by Charles A. White, M. D., Vol. I, p. 173, 1870.

†Sixth Ann. Rep. of the U. S Geol. Sur., Washington. 1885.

‡The Pleistocene History of Northeastern Iowa, by W. J. McGee, Eleventh Ann. Rept. U. S. Geol. Sur, pp. 204-205, 368 and 548.

mechanical effects of the flowing ice sheet that overran a large portion of northern North America just before the beginning of the present era. In the portions of the state affected by glacial action the ice streams planed down the pre-existing ridges and choked up the old valleys with rubbish resulting from preglacial rock-decay, or from the immediate waste and wear of the rocky ledges over which the glaciers flowed. In the drift regions, therefore, the ancient irregularities of the surface were levelled up in times comparatively recent. Since the retreat of the ice the agents of erosion have been more or less effectively at work, scarring and carving the surface of the drift-covered portions of Iowa, but the time has been too short to produce marked irregularities, much less to restore the bold forms of relief that characterized the preglacial topography.

In Allamakee county there is no mantle of drift. There are no indications of invasion by glaciers. The topographic characteristics imposed by long-continued action of solution and mechanical erosion have never been obscured or modified in any essential or fundamental degree. The surface, therefore, is gashed and furrowed in every direction by an intricate system of ramifying erosion channels. Some small areas in the southwestern part of the county are comparatively level. Ludlow and Union Prairie townships present more of the usual features of Iowa topography than any other portions of the county. Elsewhere throughout the county topographic forms are bold. Rounded, steep-sided ridges, with gorges and ravines sharply angled at the bottom, prevail, except in or near the valleys of the main drainage streams.

Looked at in the larger way we may regard the surface of the county, as carved into a few undulations of comparatively great size determined by the position of the principal drainage channels and the intervening divides. At the parting of the surface waters between the Oneota river and Village creek, there extends a long sinuous crest, broken by a few unimportant depressions, and determining the location of the wagon road for the greater part of the distance between Waukon and Lansing. This is the highest crest of the county, and the point called Iron hill, a few miles northeast of Waukon, easily overtops

every elevation included within the sweep of the horizon. Different parts of this divide receive different local names. Its eastern part is the Lansing ridge, while the middle portion is known as Lycurgus ridge.

The watershed between Village creek and Paint creek extends east from Waukon, and is followed by the roadway leading through Elon and Dalby. The divide between Paint creek and Yellow river forms a rather sharp crest that is known in part as the Mount Cherry ridge. Postville is situated on the high land south of the Yellow river, while a crest that lies partly in Iowa and partly in Minnesota marks the summit of the divide north of the Oneota. The crest between the Oneota river and Village creek is not only higher than any other in the county, but, beyond that fact, it contains the highest land, at corresponding distances from the Mississippi river, between Saint Paul and the Gulf of Mexico.

Standing on the summit of this divide one looks away across a series of ridges, apparently rising to the same horizontal plane until earth and sky blend in the undefined haze of the far off horizon. The summits of these higher ridges coincide with an old peneplain or plain of base-levelling. Near the close of the Cretaceous period the agents of erosion had removed all material that stood above the level at which the streams were capable of transporting rock detritus and the country was reduced to an unbroken expanse of low, level, marshy lands traversed by sinuous channels in which the sluggish water flowed with scarcely perceptible current.

After the completion of the Allamakee peneplain, the region was elevated, at least 700 feet, above its former position, and the streams quickly cut their channels down to the new base level, leaving the intervening divides to be brought down more slowly by the smaller and less energetic lateral currents. The flat bottom of the Oneota valley, and the corresponding plane to which the other streams have cut, mark the position of a new peneplain to which the divides will all be brought down, provided the present drainage relations are long continued. Everywhere the sides of these ridges are already deeply scarred

and furrowed by the initial branchlets of the secondary water courses belonging to the modern system of drainage.

The sculpturing referred to is repeated, not only on all the main divides, but, on a smaller scale it appears on all the secondary ridges between the different affluents of the principal streams, and even on all the ridges of less than secondary rank, until there is scarcely a quarter section of unbroken land in the typically driftless portion of the county outside the base-leveled flood plains of the larger rivers. The crests of the higher divides rise in some instances more than six hundred feet above the bottom of the valleys, and so the surface of the water at the mouth of the Oneota, or of Yellow river, has an altitude that is actually less than midway between the tops of the ridges and the level of the Gulf at the mouth of the Mississippi. Since the streams ran on the plane of the present watersheds, they have cut their valleys more than half way down to sea level.

To the traveler who has previously been acquainted with the topographic forms of Iowa only as they are developed in the drift-covered portions of the state, the extremes of relief and the intricacies and peculiarities of the topography of the driftless area come in the nature of a surprise. The deep valleys, the high bluffs, the water-carved ridges, every topographic form, indeed, are each and all wholly unique, for the other parts of the state furnish nothing with which they can in any way be compared. The gorges, canyons with high, frowning walls, dome-like hills, and other peculiarities which the region presents, have led with much reason to speaking of Allamakee county as "The Switzerland of Iowa."

DRAINAGE.

Oneota River.—The Oneota, or as it is commonly called, the Upper Iowa, is the principal river of Allamakee county. It enters the county from the west not far from the southwest corner of Hanover township, and thence pursues a sinuous course northeastwardly to near New Albin, where it joins the intricate network of channels and wider expanses, composing the labyrinth of lakes and bayous that occupy the broad flood

plain of the Mississippi, between Lansing and the northern boundary of the state.

The valley of the Oneota river is broad, flat-bottomed, and occupied by farms of exceptional fertility. The width of the valley averages about a mile, the range being from less than half a mile to nearly three miles. The valley is everywhere bounded by steep bluffs that are crowned throughout the whole course of the stream in Allamakee county by bold mural escarpments of heavy bedded limestone. The height of the bluffs ranges from 250 to 400 feet, the greatest height being found in the vicinity of New Albin. The average height exceeds 300 feet, and yet from the summit of the bluffs bordering the valley, the land still rises in swells and ridges, separated by water-cut gorges and ravines, up to the crests of the divides which have an elevation above the river of more than 500 feet. Nowhere in Iowa, outside the driftless region, are such striking irregularities in the surface configuration, such surprising examples of water-carved relief.

The bottom of the Oneota valley, as already intimated, is flat, and the river meanders from side to side through a rich deposit of alluvium that receives continual accretions through periodic overflow. In the eastern half of its course in Allamakee county the stream has long since cut its channel to base level, and there is no longer any tendency to lower the valley by erosion.

Formerly, indeed, the base level was much below what it is at present. The land stood relatively higher with reference to the waters of the Mississippi. Both the Oneota and the Mississippi scoured out their channels to a greater depth than obtains now; but owing to the choking up of the gorge of the larger stream, probably by silt brought down by the Wisconsin river, the waters along the eastern border of Allamakee occupy a higher relative position than before, and in place of cutting their channels deeper, have recently been filling them with sediments. The Oneota has thus since the close of the glacial period filled its valley near the mouth to a depth of forty or fifty feet.

Since the stream reached base level the principal changes in the valley have been produced through the effects of erosion, solution, and general weathering of the steep cliffs or walls that limit it on either side. The cliffs have been lowered as a result of the wastage perpetually taking place upon their summits; they have been gradually separated farther and farther, and the valley has widened, as a result of weathering and consequent wastage on their exposed faces. Furthermore, they have been intersected by numerous lateral gorges and ravines, and so in places have been carved into a series of jutting rounded prominences that seem to encroach upon the valley. Not infrequently the projecting headlands have been cut transversely by the agents of erosion, so as to produce a series of isolated buttes. These are usually round-topped hills more than three hundred

Figure 1. The "Elephant"—a hill of circumdenudation with Oneota river at its southern base.

feet in height, broad at the base and sloping gradually to a summit capped almost invariably with ledges of heavy bedded Oneota limestone which, on one or another side of the butte, presents vertical frowning walls twenty, thirty, or even fifty feet in height. The buttes usually have a base elliptical in outline, but so far as observed there is no constant relation between the axes of the ellipses and the direction of the valley. The plain on which the buttes stand coincides with the bottom of the valley; the buttes are masses of the original sediments of the region that have escaped the effects of destructive agencies,

standing on a base level of erosion. They all illustrate what Chamberlin has so well called topographic old age. Examples of such isolated buttes as are here described are found in the Elephant Bluff, near the center of Section 32, Tp. 100 N., R. V W.; Mount Hope, in section 34 of the same township; Owl's Head Bluff, in sections 1 and 2 of Tp. 99 N., R. V. W., and a number of others on the south side of the valley, between Owl's Head and the mouth of the Oneota. (Figures 1 and 2.)

Figure 2. Mount Hope—a hill of circumdenudation standing on the base-levelled flood plain of the Oneota river. Height above the river, 320 feet.

The topographic features bordering the valley of the Oneota proper are repeated on a smaller scale, and with some modifications, along the tributary valleys that enter from the north and south. The main tributary is Bear creek which, just before joining the Oneota, receives the waters of Waterloo creek. These two streams bring their tribute from the northwest. Both have cut their channels deep into the alternating strata of limestones and sandstones, and have formed valleys that, in their lower courses, are miniatures of the valley of the Oneota. The valleys become less and less deep as they are followed toward the sources of their respective streams, but even at the boundaries of the county the eroded gorges, in which these

streams flow, are hemmed in by walls more than a hundred feet in height. Lateral gorges again cut these walls into a succession of swelling prominences; and if the lateral gorges are traced to their origin, they will be found to begin in a multitude of divaricating channels—dry most of the year, and from a foot or two to a yard in depth—away up three, four, or five hundred feet above the valley of the Oneota, near the summits of the divides.

Other streams from the north and south come to swell the waters of the Oneota; but their dichotomously branched valleys—beginning in small erosion furrows near the summits of the dividing ridges, the whole system being spread out fan-like upon the surface with the final twigs indefinitely multiplied—are all simply repetitions of the valleys already described. The Oneota and its larger branches have cut their channels down almost or quite to base level; but the smaller lateral gorges ascend toward the divides at a steep grade, and down these, in times of heavy rains or melting snows, the waters rush with tremendous energy. Immense numbers of rock fragments are in consequence detached from the bottom and sides of the channel, and, carried along by the force of the stream, are finally spread out in a fan-shaped talus wherever the current emerges upon a plain of gentler slope. Excepting some small areas in the southwest, all the public roads of the county are, by force of the irregular topography, obliged to follow either the ridges or drainage channels without respect to section lines or points of the compass. In the valleys the small areas of tillable land are too precious to be used for highway purposes, and so the roadways are crowded to the extreme edge of the arable space, where abrupt slope or frowning wall meets the level plain. A journey over such a road is attended by the unpleasant experience, recurring every few rods, of ascending and descending the slopes of uncompacted fan-shaped piles of rock fragments carried out by recent torrents from the small lateral ravines that cut into the sides of the valley.

The Oneota river throughout the whole course in Allamakee county runs over a bed of Saint Croix sandstone. In the bluffs and sides of the valley, near the mouth of the stream, the Saint

Croix has an exposed thickness of three hundred and twenty feet.

The river enters Allamakee from Winneshiek county between bluffs in which the Saint Croix sandstone rises to a height of sixty or seventy feet. From the mouth to the west line of the county the heavy bedded Oneota dolomite imparts some of the most picturesque features of the bounding walls of the Oneota valley. Along the middle and lower course of the stream the bluffs are crowned with jutting crags and buttresses, and frowning precipices of light colored Oneota limestone underlain by from one hundred to three hundred feet of crumbling Saint Croix sandstone; but in the western part of Hanover township the vertical escarpments of the dolomite begin not far above the level of the stream.

If one starts from the mouth of Bear creek and goes northwest to the summit of the Waterloo ridge, near the northeast corner of section 18, Tp. 100 N., R. VI W., he will pass in succession over one hundred feet of Saint Croix sandstone, two hundred and fifty feet of Oneota limestone, eighty feet of Saint Peter sandstone, and one hundred feet of Trenton limestone. In this thickness of 530 feet of strata there are many lines of springs. The plane of contact between the Oneota limestone and the Saint Croix sandstone is an important water-bearing horizon, and is marked by many large springs in the neighborhood of Quandahl, Dorchester, and at a multitude of other points in the intricate system of valleys and ravines into which the surface of the northern half of Allamakee county has been carved.

Springs occur occasionally at the junction of the Oneota and Saint Peter, and again, between the Saint Peter and the Trenton; but one of the most important water-bearing horizons is found at the upper surface of a bed of shales from fifty to seventy feet above the base of the Trenton limestone. While the quality of water is unsurpassed, the supply is copious, and during even moderately dry weather all the rivulets and creeks, and even the larger streams, are fed exclusively by springs. The spring creeks have not eroded the channels in which they run. Other agencies have excavated the gorges and valleys,

and the spring began to flow only when the ordinary processes of erosion had cut the valleys down to the successive water-bearing horizons.

Village Creek begins in a series of springs north of Waukon. The shale bed near the base of the Trenton determines the level at which the waters emerge. The stream flows first over a bed of Trenton limestone, but immedately north of Waukon it cuts down to the level of the Saint Peter sandstone. Two and a half miles farther east it enters a fairly well developed valley bounded by cliffs of Oneota limestone, and thence to its mouth, a short distance below Lansing, it follows a steep-walled valley overlooked by frowning cliffs and battlements of Oneota. Soon after entering Center township the whole thickness of the Oneota is cut through, and from this point to its confluence with the Mississippi the stream flows in a channel sawed into strata of the Saint Croix sandstone. Beginning near Waukon in a number of rivulets supplied by small springs, with a channel at first that a modest foot-bridge might easily span, Village creek gathers volume from the tribute of numerous spring-fed affluents, until, swollen to the dimensions of a fair-sized creek, it finally escapes from its gorge between bluffs four hundred feet in height. Sandstone of the Saint Croix stage makes up the bluff three-fourths of the way from base to summit, and the Oneota limestone forms a cap one hundred feet in thickness. The lateral gorges and ravines opening into the valley of Village creek are, as usual in all the driftless region, dichotomously branched, and have their ultimate origin in a palmate system of shallow furrows away up near the summits of the dividing ridges. The Oneota river and Village creek are nearly parallel, and both trend northeast.

Paint Creek has its origin not far from the headwaters of Village creek. It begins as two main branches, one originating in a series of springs in and near the city of Waukon, the other rising about a mile to the southwest. The springs issue from the Trenton, and both branches flow for some distance over exposed beds of this limestone. The gradient of the valley is steep, so that at the union of the two branches, about two and a half miles southeast of Waukon, the channel has cut well down

into the Saint Peter sandstone. For six or eight miles, following the course of the creek, the Saint Peter sandstone gives character to the walls of the valley. The slopes are gentle, the bluffs are low and rounded, and pastures extend in long, easy curves down to the very margin of the stream. The slopes that were originally wooded are now, for the most part, cleared, and are not too steep to be cultivated. Between two and three miles above Waterville the steep descent carries the bottom of the valley below the upper level of the Oneota limestone, and the bluffs assume a more precipitous character on account of the crags and castles and jutting ledges resulting from erosion of the heavy bedded dolomite. At Waterville the cliffs, composed entirely of Oneota limestone, rise almost vertically to a height of one hundred and fifty feet above the stream. Three miles below Waterville, not far from the southeast corner of Paint Creek township, the bottom of the valley is excavated in strata of the Saint Croix sandstone, but the towering ledges of the Oneota, ever rising higher and higher relatively to the surface of the water, accompany the stream until it emerges upon the low flood plain of the Mississippi at Waukon Junction. At the Junction the bluffs are nearly three hundred and fifty feet in height, one hundred and fifty feet being made up of Saint Croix sandstone, and the beds of passage by which transition is made to the nearly two hundred feet of Oneota with which these majestic cliffs are crowned. Paint creek and Village creek begin near together, but they at once diverge, one flowing toward the northeast, the other toward the southeast, with an ever-widening space between them. Like other streams of Allamakee county, the main supply of water in Paint creek during periods of normal flow, comes from a multitude of springs. Delicious water, clear, cool, refreshing, wells out from the hillsides in generous volume at all the water-bearing horizons, and each spring-fed rivulet rushes off, sometimes with clamorous haste, to add its tribute to the axial stream.

Yellow River stands next in importance to the Oneota among the streams of Allamakee county. It has its sources in a number of diverging branches that rise in the southeastern part of Winneshiek county and in Ludlow and Post townships of

Allamakee. In midsummer, or during times of drouth, the main channel above Myron, in Post township, is a dry, rock-strewn river bed. All the water supplied by the tributary rivulets disappears in crevices of the much-fissured Trenton formation in which the channel is cut. Among the people living in this region it is believed that the water, losing itself in the fissures of the bedded limestone, reappears in what is known as the "Rise of the Yellow river," a very large spring which occurs on the land of Mr. Livingood near Myron (Tp. 96 N., R. VI W., sec. 3, Sw. qr., Nw. ¼). While the source of the water supply in the spring may be altogether different from what is locally believed there is here discharged a volume of water sufficient to form a creek ten or twelve inches in depth and three or four yards in width. A short distance from its source the creek flows into the channel of Yellow river and, from that point on, the bed of the stream, even in the dryest weather, is never destitute of water. The "Rise" of the river is located at the foot of a cliff of Trenton limestone seventy or eighty feet in height. The spring has been flowing in practically its present position for an indefinite period. The cliff is receding, if at all, very slowly. Its face is covered with moss and ferns. Vines clamber over the jutting edges of limestone. Trees several inches in diameter have gained a foothold at different heights of the nearly vertical scarp; and an elm, almost eighteen inches in diameter, grows within two or three feet of the base.

Like all other streams of Allamakee county, the Yellow river is dependent on springs for the normal flow in dry weather. To the midsummer traveler the springs in all these valleys are a constant joy, their number and size are a perpetual surprise. The Yellow river increases in volume by additions of generous and never-failing supplies of purest spring water from the "Rise" above Myron, till its current is checked and its characteristics, as a spring-fed stream, are lost amid the post-glacial mud beds near its mouth. From the west line of the county to near the eastern edge of Post township the Yellow river flows in a bed excavated in layers of Trenton limestone. Below Myron, in sec. 2, Tp. 96 N., R. VI W., the gorge, cut entirely in Trenton limestone, is two hundred feet in depth. The point

at which the stream cuts through the Trenton and strikes the upper surface of the Saint Peter sandstone, is a short distance west of the eastern line of Post township. At Werhan's mill, less than two miles east of the township line, the river bed is fifty feet below the summit of the Saint Peter, while about a mile farther down it cuts into the upper layers of the Oneota limestone. From a point a mile or so from Werhan's the dip of the strata coincides for a time very nearly with the slope of the river bed, for at Smithfield, in the eastern part of Franklin township, the Oneota limestone rises only twenty feet above the level of the water. Above Werhan's the dip is toward the southwest. Between Smithfield and Ion the inclination of the strata is again toward the southwest, and the river cuts deep into the massive beds of the Oneota, so that below Ion the gorge has vertical walls of the buff colored dolomite one hundred and fifty feet in height. (Figure 3.) About two miles below Ion

Figure 3 Canyon of Yellow river below Ion.

the Yellow river cuts through the Oneota into the Saint Croix sandstone. At the mouth of the river the junction of the Saint Croix and Oneota is eighty feet above the surface of the water, and the bluff that overlooks the Yellow river and the Mississippi has a height of two hundred and ninety feet.

For some distance from the mouth, three miles or more by the windings of the stream, the channel was formerly somewhat lower than at present. It had been scoured out down to a different base level from that which now obtains. Owing, however, to the ponding back of the waters of the Mississippi during the closing portion of the glacial period, or to the relative rise of the waters from some other cause, a new base level was established, higher than the old, and the stream has deposited beds of clay to adjust its plane of erosion to the new conditions.

STRATIGRAPHY.

General Relations.

The indurated rocks of Allamakee county all belong to two periods; the Cambrian, and the Ordovician or Lower Silurian. The taxonomic relations of the strata are expressed in the subjoined table.

SYSTEMS.	SERIES.	STAGES.
Ordovician.	Trenton.	Galena limestone. Trenton limestone.
	Canadian (?).	Saint Peter sandstone. Oneota limestone.
Cambrian.	Potsdam.	Saint Croix sandstone.

Geological Formations.

CAMBRIAN.

SAINT CROIX SANDSTONE.

In Allamakee county only the upper or later division of the Cambrian system is represented. All the Iowa Cambrian therefore, belongs to the Potsdam series and to the stage called by Professor N. H. Winchell the Saint Croix sandstone. The Saint Croix beds, as they are seen in Iowa, are exposed only in

the sides of bluffs, or in the bottom of erosion valleys. Nowhere do they rise to the tops of the higher bluffs bordering the valleys, much less to the summits of the chief divides.

Distribution.—The Saint Croix sandstone is exposed in the high cliffs and mural precipices facing the Mississippi river along the whole eastern border of the county. It is seen in the sides of the valley of the Oneota river throughout the whole course of this stream in Allamakee, forming everywhere the lower portion of the walls of the valley. At Gabbet's Point it rises three hundred feet above the level of the river, and from this point its elevation with reference to the stream becomes less and less until at the western boundary of the county its upper surface is only a few feet above the water in the channel. It may be traced along Village creek at ever-diminishing altitudes above the stream to near the west line of Center township. In the valley of Paint creek the Saint Croix is last seen in the southwest quarter of section 36, Tp. 97 N., R. IV. W., while along the Yellow river the sandstone dips beneath the level of the valley in section 20, Tp. 96 N., R. III W. Below the points where the Saint Croix disappears in the principal valleys it is more or less conspicuous in the valleys of all the tributary streams. It is found, for example, along Bear creek, as far as Quandahl, and in the bluffs overlooking Waterloo creek it extends up to Dorchester. Indeed, the space the Saint Croix occupies, when represented on the map, is seen to be exceedingly irregular, for it consists of narrow linear, and many times dichotomously branched areas corresponding to all the portions of the main valleys and their dendritic ramifications, that lie below the level of the upper limit of the sandstone.

Thickness.—At New Albin the Saint Croix sandstone rises to a height of three hundred and twenty feet above the grade of the Chicago, Milwaukee & St. Paul Railway. From New Albin to Lansing the trend of the bluffs overlooking the flood plain of the Mississippi is nearly parallel to the strike of the strata, so that at Mount Hosmer, the eminence above Lansing, the Saint Croix sandstone falls but little below the altitude which it attains at the northern limit of the county. At Lansing the exposed thickness of the Saint Croix may be set down at three

hundred feet. For some distance below Lansing the bluffs continue to trend nearly parallel to the strike, and the top of the Saint Croix maintains an altitude approximately three hundred feet above low water in the Mississippi. At the bend below Heytman's Station the bluffs assume a direction nearly parallel to the dip of the strata, and from this point on to the southern boundary of Allamakee county the altitude of the Saint Croix rapidly diminishes. At Harper's Ferry the upper limit of the sandstone is about one hundred and eighty feet above the river. At Waukon Junction it has descended to one hundred and forty feet, and at the mouth of Yellow river it only rises eighty feet above low water level.

The three hundred feet of Saint Croix sandstone, exposed in the bluffs from New Albin to Heytman's Station, represents only a part of the entire thickness of this formation. In boring the wells which supply the city of Lansing with water the drill penetrated layer after layer of sandstone, in all respects similar to that exposed in the bluffs, to a depth of seven hundred feet below the level of the water in the river. Adding to the amount below the water level the amount exposed in the bluffs, it will be seen that the Saint Croix has a thickness at Lansing of one thousand feet—a thickness that agrees well with observations made on this formation by Chamberlin and Irving in Wisconsin. In the wells at Lansing, at the base of the sandstone, the well borers encountered a hard crystalline rock that effectually resisted all efforts to penetrate it with the drill. They had evidently reached the westward extension of the Baraboo quartzite, a vitrified or metamorphic sandstone of Algonkian age that forms the Baraboo ranges of Wisconsin and is well exposed at Devil's Lake. In many localities in the Wisconsin river valley a sandstone, known in Wisconsin as the Postdam sandstone, but equivalent to what is here called the Saint Croix, may be seen resting directly upon the quartzite. Wherever, indeed, the base of the Saint Croix has been seen in the upper Mississippi valley it has usually been found in contact with quartzite of the same character as that composing the Baraboo ranges, and there can be little doubt that it was this same quartzite that made further drilling impracticable in the well at Lansing.

Lithological Characters.—As to lithological characters the portion of the Saint Croix sandstone exposed in Iowa is very variable. A description, omitting minute details and dealing in a general and large way with the exposures of this formation at Lansing, will convey some idea of its more prominent characteristics. The facts to be presented are illustrated in part in the following section:

1. For forty feet above the level of the river the sandstone is not exposed.
2. Beginning at forty feet above the water level and extending up to eighty feet, is an assemblage of beds varying very greatly in some respects. The sandstone is definitely stratified, it is quite incoherent, the prevailing colors are sombre—mostly dark grays or browns—but there are some narrow bands of green alternating with bands and interrupted streaks of yellow; and cross-bedding, particularly in the greenish layers, is a common characteristic.
3. Number three of the section is a bed six feet in thickness, resembling closely the underlying layers. It is somewhat harder, though portions are quite friable. The prevailing colors are shades of brown and yellow, but there are some thin green bands that, as in number two, are obliquely laminated.
4. Number four is a bed eight feet in thickness, somewhat shaly, yellow in color, and made up of thin, horizontal laminæ that break up into small angular flakes.
5. Lying upon the thin yellow beds of number four is a harder layer, gray in color and two feet in thickness.
6. Following number five is an assemblage of harder beds, varying as to their general characteristics, and twenty-four feet in thickness. Some of the beds are massive and contain more or less calcareous matter, others are more distinctly laminated. Dull, dirty colors predominate, but there are bands of red, brown, gray and yellow. Near the top of six, yellow predominates, and there is a gradual transition to the soft, yellow, calcareous shales of number seven. The massive, firmer beds of number six have been quarried somewhat extensively for building stone.

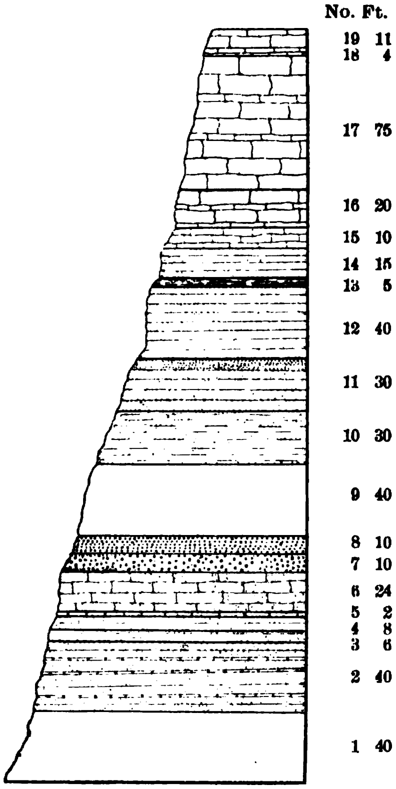


Fig. 4. Section at Lansing, Iowa.

7. Number seven is a continuation of the upper part of number six and itself grades up imperceptibly into number eight. Ten feet in thickness is

assigned, rather arbitrarily, to this member of the section. The layers are yellow in color, horizontally laminated, fine in texture, quite distinctly calcareous, and are easily split into moderately thin leaves along the planes of lamination. About the middle of this member the calcareous shales contain the remains of trilobites and a few linguloid brachiopods. Of the trilobites, *Dikelocephalus minnesotensis* Owen, is the species most abundantly represented, but there are occasional fragments of an Illænurus, differing from *Illænurus quadratus* Hall, in the form and other characters of the glabella. In general the trilobites are represented only by impressions of dismembered portions of the dorsal exoskeleton, but in two specimens of Illænurus the glabella and thoracic segments retain their normal, relative position.

8. This is lithologically very similar to the last. The beds are slightly more compact and, so far as observed, they contain no fossils. The color and general characteristics of the strata are identical with seven.

9. For forty feet above number eight the hillside is sodded over.

10. When the strata are again exposed there occurs a body of strata thirty feet in thickness, consisting of yellowish sandstone, partly soft and unstratified, sometimes harder and showing planes of bedding, all very irregular and varying both laterally and vertically in color and hardness.

11. Above the last are beds grayish in color, varying sometimes to yellow, made up of coarse, rolled quartz grains, irregularly cross-bedded; the sand becoming coarser toward the top, with shadings of brown and red and with varying degrees of hardness from the most friable to beds having a fair degree of induration. Thickness thirty feet.

12. Following eleven the rock becomes firmer, finer grained, still occasionally cross-bedded, and hard enough to stand in vertical cliffs. Prevailing colors are gray and yellow. Thickness forty feet.

13. Then follows a more friable bed, five feet in thickness, yellow and brown in color with some thin bands of gray.

14. Above thirteen there are fifteen feet of beds of passage, some quite arenaceous, others made up of sand cemented with a relatively large amount of calcium and magnesium carbonate. The beds are harder than most of those below; they are fine-grained, resist the weather and tend to form vertical escarpments along sides of the bluffs.

Above the level of number fourteen, three hundred feet above the surface of the river at low water, Mount Hosmer and all the neighboring bluffs, are made up of the dolomitic beds of the Oneota limestone. The foregoing description is intended only to give a very general conception of the characteristics of the Saint Croix sandstone as it is exposed at Lansing. With few exceptions the several beds of this formation vary in character laterally, so much so, that sections taken quite near together would differ greatly in minor details. This whole complex mass of arenaceous strata throughout its entire thickness of a thousand feet, is simply a shore deposit laid down in shallow water upon a subsiding sea bottom.

The rate of subsidence was not uniform, sometimes it was faster, and again it was slower, so that the position of any given point in the area covered by the sandstone—the site of Mount Hosmer for example—was continually changing with reference to the shore line of the land area from which the sediments were derived.

Furthermore, the movements of the sea bottom affected the ocean currents, causing them to flow sometimes in one direction and again in another. The rate of the erosion whereby the sands were furnished may well have varied with variations in the altitude of the land above sea level, as well as in the volume of rainfall, and the consequent energy of the resulting streams. At all events some causes combined to bring about perpetual changes in the nature of the deposits laid down at any given point, as well as often to produce quite different contemporaneous deposits at points not very far removed from each other.

The assemblage of beds represented by the upper part of six, all of seven, and all of eight, on the section, page —, are fairly constant over considerable areas. The sediments are fine, largely chemical, rather than mechanical, and they were laid down in quiet water, in a deeper sea that had the bottom unvexed by waves or currents. These beds represent a time of more rapid subsidence and remoter shores. The beds in question are more calcareous in the valley of the Oneota river than they are at Lansing. The calcareous constitutent increases in relative amount as the beds are traced westward until at the point where they are last seen in the Oneota valley, near the west line of Union City township, they assume the character of an earthy, thin bedded dolomite.

The fossil-bearing portion of this series represents the fifth trilobite bed of Owen; while the whole assemblage of evenly bedded calcareous strata, about thirty-five feet altogether, is the equivalent of the Saint Lawrence limestone of Winchell, as re-defined in the second volume of final reports of the Geological and Natural History Survey of Minnesota*, while it is also

*The Geol. of Minn. vol. II of Final Report; by N. H. Winchell, pp. xxi and xxii. Saint Paul, 1888.

the equivalent of the Mendota limestone of Irving, as given in the Geological Reports of Wisconsin*.

In the section at Lansing there are above the level of the calcareous beds one hundred and sixty feet of variable sandstones which are the stratigraphical equivalents of the Jordan sandstone of Winchell, and of the Madison sandstone of Irving.

A blue calcareous shale was observed near the base of the bluffs not far from New Albin. If this is present at Lansing, it lies below the level of the exposed portion of the section. It is possible that this may be the western extension of the blue, calcareous shale reported by Chamberlin as a member of the Potsdam series (Saint Croix) in eastern Wisconsin†. Only a few feet of the shale were seen at a single point above the roadway leading into New Albin from the west.

The Saint Croix sandstone as here defined is equal to the Potsdam sandstone of Hall, White, Chamberlin and McGee, as the term is used in referring to the geology of Iowa, Wisconsin and Minnesota; but it cannot be affirmed that it is equivalent to the Potsdam of New York. It embraces all that is included under the terms Potsdam sandstone, Mendota limestone and Madison sandstone in some of the writings of Irving. It is the same as the Saint Croix sandstone as finally delimited by Winchell, embracing, however, at the same time, his Saint Lawrence limestone and Jordan sandstone, which, in the second volume of reports, he associates with the lower sandstones in the Saint Croix formation. The whole assemblage of strata, so far as Iowa is concerned, represents continuous deposition under practically unchanged conditions. For a short time, during the deposition of the unusually calcareous strata associated with the trilobite-bearing beds, the off-shore conditions that must have existed somewhere throughout the whole time represented by the thousand feet of sediments, became possible, on account of unusually rapid subsidence, over northeastern Iowa and the adjacent parts of Wisconsin and Minnesota. During this short period trilobites and lingulas migrated into the region that thus offered a favorable environment; but their time of occupancy

*Geol. of Wisconsin, vol. II, p. 535. 1877.

†Geol. of Wisconsin, Vol. II, p. 262.

was short, for the old conditions of shallow water, rapid currents, coarse sediments and proximate shores were again introduced, and the progress of deposition went on much as before the unusual subsidence. When the greater subsidence that marked the close of the Saint Croix and the introduction of the Oneota took place, the Cambrian trilobites had disappeared and the sea became populated anew by an incursion of Ordovician types related to the fauna of the Calciferous sandrock of New York.

ORDOVICIAN.

ONEOTA LIMESTONE.

The Oneota limestone is one of the most conspicuous and at the same time one of the most important of the geological formations in Allamakee county. It lies directly and conformably upon the Saint Croix sandstone, the transition from one formation to the other being made through some fifteen or twenty feet of calciferous sandstone. Owen correctly describes some of the beds of passage as "Magnesian Limestone with glitering crystalline facets, and calcareo-siliceous oölite, produced by rounded grains of quartz encased in calcareous cement*." The sand grains indeed are coated with a number of successive layers of calcareous material, and the rock, on fresh fracture, often presents all the appearance of a true oölite.

The Oneota limestone was first described by Owen, and in his reports of 1849 and 1851 it was called the Lower Magnesian limestone†. This name has been retained by White, Chamberlin, Irving and some others who have studied the geological formations of the upper valley of the Mississippi, though Hall in his geology of Iowa refers to this formation as the Calciferous sandstone. Winchell in his latest rectification of the Cambrian and lower Ordovician strata in Minnesota, divides Owen's

*Owen's Geol. Sur. of Wis., Iowa and Minn., Phila., 1852, p. 52. The "Sixth trilobite bed" evidently corresponds to the beds of passage between the Saint Croix and the Oneota.

†In the Report of a Geol. Exploration of Iowa, Wisconsin and Illinois made in the autumn of the year 1839, Second Edition 1844, Owen frequently refers to this formation as the "lower magnesian limestone," (pp. 21 and 31) but the term is used descriptively and not as a specific name. The term is also used in figures 6 and 7, Pl. I, of the same volume, but whether as a specific or as a merely descriptive term, cannot be inferred.

Lower Magnesian limestone into (1) the Main Body of Limestone, (2) the New Richmond Beds (sandstone), and (3) the Shakopee Limestone. The term "The Main Body of Limestone," he adopts from Irving. McGee claims that the "Main Body of Limestone" is the only part of Owen's Lower Magnesian limestone to which the original name could now, with any propriety be applied. He claims further that the original name "is objectionable in that its correlative element has become meaningless since the division of the original Upper Magnesian into three formations" and so he proposes to call the assemblage of strata between the top of the Saint Croix and Irving's New Richmond sandstone the Oneota limestone, a term derived from the Indian name of the river along which the formation attains its typical development*. The part of Owen's Lower Magnesian limestone that corresponds to the New Richmond sandstone and Shakopee limestone of the Minnesota geologists McGee refers to the Saint Peter sandstone. Hall and Sardeson would unite under the somewhat comprehensive name of the Magnesian Series of the Northwestern states, all the strata from the base of Winchell's Saint Lawrence limestone to the top of the Shakopee of the same author†. The stratigraphical divisions and faunal changes occurring between the limits mentioned are fully recognized; but the fact that the beds represent continuous deposition during a period characterized by the recurrence of conditions that alternately favored the deposition of dolomite and sandstone, has induced these authors to group all the strata referred to under one comprehensive term.

The New Richmond sandstone of Minnesota and Wisconsin is represented in Allamakee county by a number of inconstant, thin arenaceous beds that are interstratified with dolomite. Above the uncertain sandstone layers the formation is wholly dolomitic up to the base of Owen's Saint Peter sandstone. There does not seem, therefore, to be any call for formational divisions in this part of the geological column in Iowa; and

*McGee. Pleistocene History of Northeastern Iowa. Eleventh Ann. Rep. U. S. Geol. Surv., p. 333.

†The Magnesian Series of the Northwestern States. By C. W. Hall and L. W. Sardeson, Bull. Geol. Soc. of Am., Vol. II, pp. 167-198.

though McGee's name, Oneota limestone, is adopted in the reports of the present Iowa Geological Survey, it is modified to the extent of making it co-extensive with the Lower Magnesian limestone of Owen. It will thus include all the dolomitic beds with the thin layers of intercalated sands up to the base of the purely quartzose deposit that distinctively and beyond question belongs to the Saint Peter sandstone. The sandstone beds thus included in the Oneota, as compared with the beds of dolomite are wholly subordinate in importance up to the limit here indicated. The lower ones at least are furthermore lithologically different from the Saint Peter in being firmer and more conpact and in having the sand grains enlarged by secondarily deposited silica that has assumed the crystalline form and causes a characteristic sparkling in the sunshine owing to the reflection of light from numerous crystalline facets. Moreover these thin, intercalated arenaceous layers differ in number, thickness and in stratigraphical position in different localities, so that any effort to unite them with the Saint Peter sandstone would require the use of a line of separation between the two formations that could be defined only with much difficulty. On the other hand the base of the great body of incoherent sands that undoubtedly belong to the stage of the Saint Peter, presents a plane that is fairly constant and easily recognized.

Apart from the thin beds of sandstone that occur in it at different elevations, the Oneota formation is made up of more or less massive layers of dolomite. The colors range from white to buff or yellow. Beginning ten or fifteen feet above the Saint Croix sandstone there are thirty or forty feet of evenly bedded, fine-grained limestone in layers varying from three inches to three feet in thickness. Above this there are occasional beds suitable for quarry stone, but in general the rock is massive, with few planes of bedding, and these are irregular and often many feet apart. The massive beds are rather coarse, vesicular, rough and gritty to the feel, and highly charged along certain planes with concretionary nodules and irregular masses of chert. The last fifty or sixty feet in ascending towards the Saint Peter sandstone are characterized by the presence of beds of sand and shale interstratified with the

magnesian limestone. The sandstone layers, as already noted, differ as to number and position in different localities, and it does not seem possible to recognize any one as sufficiently constant to mark a definite horizon. It is in the last fifty or sixty feet that the Iowa equivalents of the New Richmond sandstone and the Willow river limestone of Wisconsin, or the New Richmond sandstone and Shakopee limestone of Minnesota are found. It is the last fifty or sixty feet that McGee would unite with the Saint Peter sandstone, but apparently the true relations of the beds under consideration are with the underlying body of dolomite.

Surface Distribution.—The Oneota limestone crowns all the bluffs along the Mississippi from New Albin to McGregor in Clayton county. It forms the castles and pillars and high buttressed walls that give grandeur and character to the picturesque scenery along the whole valley of the Oneota river and its affluents in Allamakee county. In the valley of Village creek it extends with its usual characteristics from the mouth to near the intersection of the stream with the line that passes north and south through the middle of Makee township. On Paint creek it forms conspicuous bluffs and precipices along the sides of the valley to a point a mile and a half above Waterville. Above Waterville the cliffs of Oneota gradually diminish in height until they fade out on account of the formation passing beneath the level of the rounded contours and gentler slopes indicative of the region underlain by the Saint Peter sandstone. Along Yellow river the frowning walls and precipices of Oneota are conspicuous to a short distance below Volney. Above this point the upper surface of the Oneota rises but little above the level of the river. Owing to the easily eroded character of the overlying Saint Peter the sides of the valley are characterized by gentle slopes nd low rounded swells that are in marked contrast with the bolder relief produced by the more obdurate magnesian limestone when exposed, as it is farther down the stream, to a greater thickness. The upper surface of the Oneota finally disappears below the level of the river in section 4, Tp. 96 N., R. V W., a short distance below Werhan's mill.

Concerning its distribution at the surface outside the bottoms and steep walls of the valleys, the Oneota limestone occupies a number of very irregularly shaped isolated areas that altogether defy anything like ready or brief description. All are in the northeastern half of the county. In many cases they are small, island-like patches crowning rounded eminences, again they are narrow, sinuous, fringing belts following the irregular contours upon the long slopes that separate the tops of the precipitous cliffs facing the valleys from the summits of the more or less distant divides. Sometimes the areas are individually large enough to embrace a number of productive farms, as erosion has produced broad shelf-like plateaus between the crumbling sands of the Saint Croix on the one side and the Saint Peter on the other.

Thickness.—In thickness the Oneota limestone ranges from 200 to 250 feet. The average is probably about 230 feet. It is most fully developed along the Oneota, or Upper Iowa river, and its branches. Nowhere, so far as observed, is the whole thickness to be seen in a single section. At some points there may be nearly or quite 200 feet included between the roadway at the foot of the steep-sided bluffs and the top of the battlemented ledges that frown down from the summit. The layers of limestone decay unequally through the effects of weathering, and though the walls of the valley seem almost vertical, some portions of the section are always concealed by sod or talus. In the perpendicular faces of the projecting summit ledges, continuous sections of forty, fifty or even sixty feet are often exposed, and in the dry rocky channels that in rainy weather carry tumultuous torrents from the higher slopes, we may make out the succession of beds for a hundred feet or more. It is a very unusual thing, however, to find a continuous natural section exposing half the thickness of the formation.

In the bluffs about one mile below the mouth of Bear creek (Tp. 100 N., R. VI W., sec. 36, Se. qr., Se. ¼), we have the following typical section, beginning at the level of the roadway that follows the valley:

		FEET.
4.	Oneota limestone, partly concealed by talus, and partly exposed in projecting vertical ledges forty or fifty feet in height	180
3.	Beds of passage, partly arenaceous and partly calcareous, some of the layers made up of rounded sand grains cemented with dolomite	15
2.	Hard layers of concretionary sandstone, the mamillary and botryoidal sandstone of Owen (Saint Croix)	15
1.	Soft Saint Croix sandstone, sometimes cross-bedded, but more frequently without stratification planes of any kind; brown and yellow in color	100

Fauna of the Oneota Limestone.—The Oneota limestone is quite barren so far as relates to fossil remains. Throughout the greater part of its thickness one may search indefinitely without finding any evidence of the existence of life while the beds of dolomite were forming. Dr. White* says that "the only fossils that have been found in this formation in Iowa are, so far as known, a few traces of the stems of crinoids found near McGregor." Whitney†, speaking of indications of organic life in the Lower Magnesian (Oneota) limestone, says that "In Iowa, indeed we have observed nothing of the kind." Owen, in his report on the Geological Survey of Iowa, Wisconsin and Minnesota, p. 60, enumerates a few genera that are represented in this formation but does not give localities. Whitfield describes a few species from the Lower Magnesian of Wisconsin in the Geology of Wisconsin, Vol. IV. Professor N. H. Winchell found Orthoceras, Ophileta and Pleurotomaria in cherty beds of this formation in Minnesota. In the proceedings of the Philadelphia Academy of Science for 1870, Meek describes a species of Raphistoma from the horizon of this limestone in Minnesota. So far as relates to Iowa, the largest collection illustrating the fauna of the Oneota limestone was made partly in Allamakee, and partly in Clayton county, by Mr. F. H. Luthe, formerly of McGregor. This collection was studied and described by Calvin‡.

The recognizable forms included: Murchisonia, species undetermined. Tryblidium, species undetermined, *Metoptoma alta*

*Report of the Geology of Iowa, vol. I, pp. 173-174.

†Hall's Geology of Iowa, p. 337.

‡Bul. from Lab. Nat. Hist. of State University of Iowa, vol. II, No. 2, pp, 189-193, American Geologist, vol. X, pp, 144-148,

Whf., *Straparollus claytonensis* Calvin, *S. pristininiformis* Calvin, *Raphistoma pepinense* Meek, *R. multivolvatum* Calvin, *R. paucivolvatum* Calvin, *Holopea turgida* Hall, *Orthoceras primigenium* Vanuxem, and *Cyrtoceras luthei* Calvin. In addition to the genera and species enumerated above Mr. Luthe's collection contained a few imperfectly preserved masses resembling in structure some forms of the Stromatoporoidea. All the specimens in the collection came from thin bands and irregular masses of chert that are more or less common throughout the upper half of the Oneota. With the exception of a single imperfect specimen of *Straparollus claytonensis* none of the species mentioned above are at present known from the masses of limestone making up the main part of the Oneota, or from the intercalated sandstones and shales in the upper part of the formation.

In the limestone portions of the Oneota, however, up near the top of the formation, there are beds that are composed wholly of large laminated concretion-like masses that bear a striking resemblance to some forms of Stromatoporoids. The individual masses vary from a few inches up to several feet in diameter. The largest individuals were seen in a road cutting on the north side of Yellow river a short distance below Volney. At this point there were some that were two or three feet in thickness and eight or ten feet in horizontal diameter.

Objects having a similar structure, but obviously much smaller than those observed in Iowa, have been described by Professor N. H. Winchell from about the same horizon in Minnesota. Professor Winchell refers the specimens to Hall's genus Cryptozoon and proposes for one of the larger forms which has a diameter of only about sixteen inches, the specific name *Cryptozoon minnesotense.* There may yet be reasonable doubt as to whether these problematic structures are really organic. The individuals tend to split into concentric portions along the planes of lamination. The upper surface, taking it as a whole, is generally convex, but the surface of each lamina is molded into a great number of comparatively small low rounded elevations that vary from half an inch to more than two inches in diameter.

Taxonomic Relations.—On stratigraphical grounds Professor James Hall and others have referred the Lower Magnesian (Oneota) limestone to the same horizon as the Calciferous sand rock of New York and Vermont. It may now be referred to the same horizon on paleontological evidence. *Metopotoma alta* Whitfield, *Holopea turgida* Hall, and *Orthoceras primigenium* Vanuxem, are species common to the eastern Calciferous and the western Oneota. Tryblidium and Murchisonia are represented in the western formation by species that are very similar to representatives of the same genera on the Vermont shore of Lake Champlain, if they are not indeed identical. The species of the other genera from the chert beds of the Oneota bear a close resemblance to species from the Calciferous beds of Vermont. There can be little doubt as to the essential equivalence of the two formations. At Fort Cassin and other points in the Champlain valley the beds that furnish a fauna essentially equivalent to that of the Oneota limestone pass up without stratigraphical interruption into beds that furnish *Asaphus canalis* Conrad, and other species that show decided affinities with forms from the Birdseye and Trenton limestones of New York. The relations of the Calciferous sandrock of the Champlain valley are paleontologically more intimate with the overlying Trenton than with the underlying Potsdam. The formation belongs to the Ordovician or Lower Silurian and not to the Cambrian, and the same statement may be made with respect to its equivalent, the Oneota limestone in northeastern Iowa.

SAINT PETER SANDSTONE.

General Description.—The term Saint Peter sandstone will be used here in the sense in which it has been employed by Owen, Hall, White and all other writers on the geology of the region under consideration except McGee. As already noted McGee proposes to unite with the Saint Peter so much of the underlying formation as represents the Shakopee limestone and New Richmond sandstone of Minnesota. Limiting the term in accordance with its original application, the Saint Peter sandstone of Allamakee county embraces a body of but slightly

coherent arenaceous deposits having an average thickness of about eighty feet, and lying between the fairly well defined summit of the Oneota and the very definitely marked bed of shale that is found everywhere throughout the county at the base of the Trenton, The formation is made up almost entirely of water-worn grains of quartz. The amount of foreign matter mingled with the quartzose sand is so small that in many cases it may be left out of consideration. While some of the beds, however, are pure white, the great bulk of the formation is more or less tinged with shades of brown, red or yellow, owing to the presence of small amounts of ferric oxide in different degrees of hydration. The colors are often very bright and distinct, and in this respect are in marked contrast with the dingy shades that characterize the greater part of the Saint Croix.

The Saint Peter sandstone is in some places practically as incoherent as when the beds were first laid down in the Ordovician sea. In portions exposed to the weather for some time the constituent sand grains become more or less cemented at and near the surface, but on breaking through the thin crust it is found that the unexposed beds have suffered so little change since they were first deposited, that fragments two inches in diameter may be crushed in the hand, or the whole body of sand may be dug out easily with the spade. At a large proportion of the localities where the Saint Peter is exposed the sandstone is so far indurated as to admit of being taken out in blocks, but the blocks may easily be knocked to pieces with the hammer, or they may be crushed with a comparatively small amount of pressure. In a few instances the beds are sufficiently hard to serve very well as building stone, and in some places they are quarried and used in making foundations for barns and other similar structures. On the land of Mr. Fred Hansesmeier (Tp. 98, N., R. V W., sec. 27, Se. qr., S. ½), about three miles east of Waukon, there are ledges of Saint Peter sandstone curiously mottled and streaked with bright red, mingled with patches of pure white. These ledges are hard enough for use as building stone and they have been so used to a limited extent.

Near Mr. Heffner's (Tp. 96 N., R. V W., sec. 14, Sw. qr., Nw. ¼), there are vertical ledges of Saint Peter sandstone that have weathered into massive, irregular detached blocks, three to ten feet in diameter, and piled one on another like some example of heavy masonry. The sandstone at this exposure is hard enough for use in ordinary walls and foundations. Other similar examples occur throughout the county, but in general the Saint Peter sandstone has so little cohesion as to be altogether unfit for use as building stone.

Figure 5. Effect of weathering on hard beds of Saint Peter sandstone near Heffner's.

The upper portion of the Saint Peter formation, for a few inches only below the plane of contact with the basal shale of the Trenton, often becomes very highly charged with iron oxide. The overlying Trenton limestone contains a considerable amount of pyrites together with some ferric oxide and ferrous carbonate. It has suffered decay on a large scale as a result of solution. For unmeasured periods the meteoric waters, on their way to the channels of drainage, have flowed over the surface or found their way into innumerable cracks and crevices that intersect the beds of limestone, and have dissolved and carried away the calcium carbonate to an extent that is hardly conceivable. The insoluble residue contained, among other things,

the pyrites of iron with which the limestone was charged, and this mineral, after undergoing oxidation, has been carried down and deposited in the uppermost layers of the insoluble Saint Peter sandstone. On some long slopes that still show beds of Trenton limestone above the Saint Peter, and where for an indefinite period solution has been more effective than mechanical erosion in disintegrating and removing the indurated rocks, the sandstone often projects beyond the general contour and forms a terrace having its horizontal surface coincident with the plane of contact between the two formations. As compared with the limestone the siliceous deposit is relatively insoluble, and so decays but slowly if at all from the effects of solution. The ferruginous deposit in and upon its surface layer enables the sandstone to resist for a time the rather feeble effects of mechanical erosion, and thus is brought about the unusual phenomenon of a hard, compact limestone receding, as a result of wastage, more rapidly than a friable sandstone.

Topographic Features.—The ferruginous stratum in the uppermost part of the Saint Peter is best developed in regions over which the Trenton has been almost, or altogether, removed. In some places from which the limestone has been completely stripped, there are knobs and ridges of Saint Peter sandstone rising forty or fifty feet above the plain on which they stand, showing at the summit the hard ferruginous band that was developed beneath the slowly vanishing Trenton, still preserving a record of the exact position once occupied by the base of this formation. An excellent typical example of such protected outlying masses of the upper portion of the Saint Peter is found in the small, conical hill which rises abruptly from the level of the surrounding region near the northeast corner of section 19, in the western part of Lansing township. The height is forty feet above the roadway that passes near its base. The sides are too steep for cultivation and so a portion of the original forest has been permitted to occupy its summit and lateral slopes, a fact that adds to the apparent elevation when the hill is seen from a distance. The crown of the hill is protected by a thin layer of hard ferruginous sandstone with

enough of the cementing ferric oxide to entitle it to rank as a fair grade of iron ore.

A little farther to the southeast, in section 20 of the same township, a church has been built in a conspicuous situation on the west end of a long, narrow, wooded ridge, that like the knoll in section 19 is made up of the upper part of the Saint Peter sandstone protected by a relatively thin but highly indurated layer cemented with ferric oxide. There are many similar outlying masses of the upper half of the Saint Peter in the southeastern part of French Creek township and the western part of Lansing. In sections 27, 34 and 35 of Makee township there are examples of the same kind, while in the southeast quarter of section 6 of Taylor township, there are some prominent wooded ridges of Saint Peter sandstone illustrating the same geological and topographical phenomena. Such ridges, hills, and bosses of sandstone as those above noticed, are indeed characteristic features of the topography in all the portions of the county that lie just outside the edge of the receding Trenton limestone.

Distribution.—The area occupied by the Saint Peter sandstone does not admit of accurate description. It occurs in long, narrow, sinuous belts around the margin of the region covered by the Trenton limestone. There are outlying patches here and there. Seldom do the continuous areas occupied by this formation have a width of two or three miles. More frequently they are mere narrow bands along hill sides with a horizontal extent limited to a few yards. With the possible exception of Ludlow and Post, the plane in which the sandstone lies is intersected by the strongly undulated surface at numerous points in every township of the county; and one traveling in any direction, except along the crests of the dividing ridges or following the troughs of the main drainage valleys, encounters exposures of it every few miles.

Fauna of the Saint Peter Sandstone.—Thus far in Iowa the Saint Peter sandstone has afforded no traces of fossils. In the Fourth Annual Report of the Geological and Natural History Survey of Minnesota, page 41, Prof. N. H. Winchell describes a small linguloid brachiopod from the upper part of the formation, near Fountain, Fillmore county, Minnesota, under the name of

Lingulepis morsensis. Prof. Chamberlin, in the Geology of Wisconsin, vol. II, page 288, mentions the discovery of Scolithus tubes in beds of the Saint Peter in eastern Wisconsin. In the Bulletin of the Minnesota Academy of Sciences, vol. III, No. 3, page 318, Sardeson gives a list of fossils from the Saint Peter sandstone near Minneapolis. The collections embrace casts of Gasteropods and Lamellibranchs belonging to the genera Maclurea, Murchisonia, Cypricardites and Modiolopsis. The fauna of the Saint Peter as indicated by Sardeson's collection is closely related to that of the Trenton, if not identical with it, and lends support to the views of those geologists who would correlate the Saint Peter of the Upper Mississippi with the Chazy of New York.

The porous character of the entire formation in Iowa, and the lack of cohesion among its constituent particles, do not afford conditions favorable to the preservation of organic remains. Even had the sea, during the age of the sandstone, abounded in organic types with skeletal parts, capable under favorable circumstances of becoming fossilized their preservation till now in such a deposit as the Saint Peter would be highly improbable. On the other hand it is more than probable that the conditions attending the laying down of the sandstone precluded the development of any extensive fauna so long as the work of deposition was in progress. The mechanical action of the strong and constant currents necessary to wash and assort the material as it was brought down from the land and free it completely from all clayey and other finely comminuted particles that must necessarily have been present in the original products of land erosion, could scarcely fail to make it well nigh impossible for sensitive types of life to exist within the area of sedimentation.

TRENTON LIMESTONE.

THE SAINT PETER SHELL LIMESTONE OF OWEN.

In Allamakee county the Saint Peter sandstone ends abruptly without noticeable change of characters. It is followed in ascending order by a bed of bluish or greenish shale that constitutes the lowest member of the Trenton formation. This

basal shale, five or six feet in thickness, is followed by beds of limestone that in most localities are at first dolomitic; but in some places they exhibit the usual characteristics of the calcareous beds belonging to the typical Trenton. There are no beds of passage. The line of juncture between the Saint Peter and Trenton is probably the most definitely marked geological horizon in all northeastern Iowa.

General Description.—The Trenton limestone is a term applied to an assemblage of strata that vary considerably among themselves and yet, when viewed as a whole, present a fairly consistent series of physical and paleontological characteristics. Some of the beds are calcareous shales, others are shaly limestones, some are dolomites, while still others are nearly pure accumulations of calcium carbonate. The formation begins with the bed of shale already mentioned, five or six feet in thickness, and resting conformably on the Saint Peter sandstone. This basal shale is seen in all parts of the county wherever the contact of the two formations is exposed; and southeast of a line drawn from Postville to New Albin it is invariably followed by beds of dolomite, having an aggregate thickness of twenty or twenty-five feet. This dolomite is the equivalent of the Lower Buff beds of the Wisconsin geologists*. As developed in Iowa the dolomitic beds are in heavy layers from six inches to three feet in thickness, and afford a very excellent quality of building stone. They are well seen in the valley of Paint creek, about two miles below Waukon. In section 6, of Paint creek township, they are exposed, and have furnished the material used in building the walls of the West Paint Creek Norwegian Lutheran church and other structures of less importance. While they are a fairly constant feature of all the natural sections that include this part of the geological column, the most instructive exposure, and the one that best illustrates the character of these dolomitic beds, was observed near the point where the wagon road intersects the south line of the southwest quarter of section 10 in Franklin township. At this exposure the beds in question are made up

*Geology of Wisconsin, vol. II, page 291.

of very hard, compact, yellow magnesian limestone, with few or no fossils. They have been quarried to a limited extent, and are capable of furnishing blocks three feet in thickness and of almost any desired dimensions as to length and width.

Above the Lower Buff beds the Trenton limestone of Allamakee county presents a great variety of lithological characters. There is a continual alternation of limestone and shales, the limestone, on the whole, predominating. As a rule the limestone is dark colored, with dull blue and slaty shades in the unleached portions of the beds. In texture it is fine grained, compact, and breaks often with conchoidal fracture. The beds are usually thin, from three to six inches being the ordinary thickness, though some beds may attain a thickness of ten or twelve inches. Layers that seem perfectly compact when taken from the quarry often break up into thin laminæ after exposure to the weather. The effect of weathering is well seen in all the exposed cliffs of this formation. Owing to cleavage of the

Figure 6. Effect of weathering on exposed ledges of Trenton limestone. Exposure on Saw Mill creek, north of Postville.

original strata along the planes of lamination the cliff appears to be made up of beds only an inch or two in thickness, while the laminæ, resulting from such cleavage, are again broken

vertically into small fragments six or eight or ten inches in diameter. (Figure 6.)

Beds presenting fairly uniform characteristics over a large area begin about thirty feet above the base of the formation and have a thickness of between thirty and forty feet. They consist of thin layers of limestone alternating with shales, the limestone layers being very irregular in their distribution and often having a very limited lateral extent. Shale is greatly in excess as compared with the limestone, and the whole bed, argillaceous and calcareous portions alike, is highly fossiliferous. The thin calcareous layers that occur in the shale are usually nothing more than masses of brachiopod shells and bryozoans—sometimes broken and comminuted, not infrequently entire—all cemented into a compact limestone. Fossils occur also in great numbers, and in the most perfect state of preservation in the argillaceous portions of the bed, and are freed from the matrix by weathering wherever the shales are exposed. The upper portion of the shale bed is highly charged with calcareous nodules, along with which it contains, among other monticuliporoids, immense numbers of the small, mostly hemispherical, coral-like bryozoans that were formerly known as *Chœtetes lycoperdon*, but which may now probably be referred to *Prasopora simulatrix* Ulrich. Weathered out of the shale or lying partly embedded upon the surface of the calcareous laminæ the collector may obtain beautiful examples of *Orthis subæquata* Con., *O. bellarugosa* Con., *O. tricenaria* Con., *Platystrophia biforata,* small variety resembling in form *P. acutilirata* Con., *Strophomena rugosa* Rafinesque, *S. incurvata* Shepard, *Rhynchotrema ainsliei* N. H. Winchell, *R. inæquivalvis* Castelnau, and many other species characteristic of the lower Trenton. The beds under consideration contain some layers of very fine argillaceous shale which, being impervious to water, determine the position of numerous springs along the slopes upon which this shale outcrops. When the dip of the strata is normal—that is, toward the southwest—the springs occur on the north and east sides of the valleys.

Above the shale bed there occurs a body of hard limestone with layers from three to six inches in thickness. Fossils are

less plentiful than in the calcareous layers associated with the underlying shale. The rock is firm, fine grained, blue or slaty in color on fresh fracture, but weathers, on exposure, to various shades of gray or buff. These beds are quarried near Waukon and elsewhere, and some of the layers afford a very durable building stone. Great care, however, must be used in making the selection, for some beds that appear to be perfectly firm and homogeneous, split badly into thin laminæ and then crumble into small angular fragments upon continued exposure to the weather.

Limestone of essentially the same character as that quarried near Waukon occurs, with slight variations and occasional interruptions by thin beds of shale, to near the upper limit of formation. North of Postville, in the southeast quarter of section 20 of Postville township, we find first an exposure of yellowish, soft limestone with much chert, which doubtless represents the lower beds of the Galena. Below the Galena there are twelve or fifteen feet of bluish shales with no fossils and then there follows in descending order about sixty feet of fossiliferous shales and shaly limestones. The main body of the Trenton limestone, about 150 feet in thickness, and exhibiting what may be called the typical characteristics of the formation-lies between the base of the shales and shaly limestones seen north of Postville, and the top of the fossiliferous shales exposed near Waukon. Between these two limits the formation is predominantly calcareous, and some of the beds furnish a fairly good quality of building stone.

Distribution and Relation to Drainage.—The Trenton limestone is distributed most extensively in the southwestern part of Allamakee county. It is practically continuous over Post and Ludlow townships, but the ramifying valleys of Village creek, Paint creek and Yellow river cut iuto the eastern margin of the area occupied by this formation and divide it into a series of irregular narrow belts that coincide with the crests of the higher ridges. The three streams mentioned above all have their origin within the Trenton area, but they do not flow far before cutting through to the underlying formations. On the other hand the Oneota or Upper Iowa river runs over the

Saint Croix sandstone throughout its whole course in Allamakee. North of the Oneota the Trenton limestone occupies the higher elevations in Waterloo and Union City townships.

The Trenton limestone is very extensively fissured, and the fissures communicate one with another over areas of considerable extent. The surface waters are drained into these subterranean fissures through numerous funnel-shaped "sink holes" that vary from a few yards to forty or fifty yards in diameter. These singular, basin-shaped depressions in the surface constitute one of the constant and characteristic features of the Trenton area and might serve as a reliable guide in tracing the distribution of the formation under consideration even if there were no other indications of its presence. In the region about Rossville the "sinks" are particularly numerous aud seem actually to crowd each other in some of the fields and pastures. The area underlain by Trenton limestone has most perfect drainage, so much so that wet land, even in seasons of most copious rainfall, is something altogether unknown. The waters that find their way into the fissures of the Trenton reappear, at least in part, in the springs that well out from the sides of every valley and furnish the constant supply for all four of the main drainage streams.

The Fauna of the Trenton.—The Trenton fauna is too extensive to be discussed here except in a very general way. The strata of the Trenton afford the earliest, and in some respects the best examples among the Paleozoic strata of Iowa, of organically formed limestones. Many of the beds are nothing but consolidated masses of the comminuted skeletons of brachiopods and other marine types of animals. The rate at which the strata accumulated on the bottom of the old Trenton sea depended on the rate at which successive generations of shell-bearing animals secreted calcareous skeletal parts during life and contributed the same at death as an addition to the slowly growing beds of limestone. The exuviæ of animals were piled up simply where the creatures lived and grew and died, and the remains of each generation buried out of sight the more or less fragmentary skeletons of the next preceding.

In the Trenton fauna brachiopods predominate with respect to numbers, both of individuals and of species; the greatest expansion of the class taking place in the families Strophomenidæ and Orthidæ. Among mollusks there are only a few Lamellibranchs. Gasteropods are comparatively numerous, the genera Raphistoma, Maclurea, Subulites and Murchisonia being the most characteristic. Orthoceras, Cyrtoceras and Trochoceras are the prevailing genera of the Cephalopoda. Trilobites are very rare within the limits of Allamakee county, a fact not easy to explain, when we consider the abundance of fragmentary remains belonging to this group in certain beds of the Trenton in Fayette, Howard and some other counties only a short distance to the westward. A single pygidium of *Asaphus* (*Ptychopyge*) *ulrichi* Clark, remarkable in having the furrows defining the constituent segments unusually distinct, was found associated with *Lingula iowensis* Owen, near the top of the limestone portion of the formation north of Postville, and the head and thorax of *Ceraurus pleurexanthemus* Green, was collected from the second shale bed near Waukon.

In the shales which lie almost immediately beneath the Galena limestone, north of Postville, there occurs an interesting fauna, markedly distinct from the faunas of the beds below, and characterized by the presence of *Rafinesquina minnesotensis* N. H. Winchell, *Orthis* (*Plectorthis*) *kankakensis* McChesney, a distinct variety of *Orthis* (*Plæsomys*) *subquadrata* Hall, and what seems to be an undescribed species, related to the last, but differing from *O. subquadrata* in the much finer and much more numerous costæ ornamenting the surface of both valves. This fauna resembles in some respects the fauna referred by the geologists of Minnesota to the Hudson river shales; but in Allamakee county it occurs beneath the Galena limestone, while Hudson river shales are not found until an altitude more than a hundred feet higher is reached. About six miles southwest of the point where the species noted above were collected, there are some prominent ridges containing at the summit heavy beds of Niagara limestone, while at the base there are occasional exposures of shales of the Maquoketa or Hudson river stage. In the dolomite quarries of Mr. Wilkes

Williams, near the northeastern corner of Fayette county, the Niagara limestone is taken out down to its junction with the shales, but there are no exposures of these shales in Allamakee county.

GALENA LIMESTONE.

The Galena limestone plays a very unimportant part in the stratigraphy of Allamakee county. It is only at a few points along the southern border of the county that this formation is seen at all. The basal portions only are present, and they follow conformably the alternating beds of shale and limestone that mark the close of the Trenton. North of Postville (Tp. 96 N., R. VI W., sec. 20, Se. qr.), the wagon road cuts through some soft, yellowish, chert-bearing beds of limestone that represent the earlier layers of the Galena stage. At this point the deposits are worthless, considered economically, but about half a mile south of Postville, in Clayton county, there is an exposures of the Galena that has been quarried on a small scale for building purposes. In the southwest quarter of section 25 and along the western boundry of section 36 in Franklin township (Tp. 96 N., R. V W.), there are exposures of Galena limestone of finer texture than those seen farther west, while in Clayton county, a short distance north of Luana, as well as north of Monona, the formation is evenly bedded, and occurs in hard, compact layers varying from six to ten inches in thickness. At these points it has been quarried somewhat extensively, and for all ordinary uses it affords building material of very excellent quality. The formation is again seen in the southwest quarter of section 32, Linton township (Tp. 96 N., R. IV W.). There are here several exposures and all present the usual characteristics of the lower portions of the formation. Without specifying the individual outcrops farther it is sufficient to say that this limestone is developed in Allamakee county only on the upper portions of the divide south of Yellow river, from Postville to near the western border of Fairview township. Only the basal members of the formation are thus included within the limits of the county. The Galena limestone in Allamakee is of little economic importance. It contributes no special features to the

topography. Its altitude above the level of the water in Yellow river is about 300 feet. Very few fossils were observed in beds of the Galena stage in the region here under discussion. But one species indeed, the *Rhynchonella perlamellosa* Whitfield, was found in condition for satisfactory identification.

No deposits of indurated rocks younger than the Galena were observed in Allamakee, although it is quite certain that the Maquoketa shales and the Niagara limestone originally overspread a large portion, probably all, of the county. Three miles south of the county line, on the Williams estate (Tp. 95 N., R. VI W., sec. 19, and Tp. 95 N., R. VII W., sec. 24), a conspicuous ridge rising abruptly above the level of the plain to the north is found to be constructed of Maquoketa shales capped by some twenty feet of massive Niagara limestone. The ridge in question is simply an outlier made up of portions of strata of the formations named which have escaped the effects of solution and mechanical erosion whereby the surrounding country has been stripped of deposits aggregating probably hundreds of feet in thickness. There are reasons for believing that the whole of Allamakee county lay beneath sea level and was the theater of active processes of sedimentation until at least the close of the Silurian.

SUPERFICIAL DEPOSITS.

SOILS.

Many causes have united to produce the soils of Allamakee county. In the first place practically all the rocks that overspread this, as well as every other county of Iowa, were made up of a mixture of soluble and insoluble materials. Of these rocks the limestones contain the largest amount of soluble matter, the shales and sandstones the least. As soon as the region was elevated above sea level, at or near the close of the Silurian, the sedimentary deposits were promptly attacked by meteoric waters as well as by the chemically active constituents of the atmosphere. Mechanical erosion was probably feeble at first, for the region rose but little above the sea; but the chemical action of the agents named, as they came in contact with

the newly exposed surface, or penetrated deeply into the strata along cracks and fissures, had the effect, within the zone of their activity, of removing the soluble constituents of the strata and leaving the insoluble clay, sand, nodules of chert, iron oxide and whatever else was incapable of passing readily into solution, as an unconsolidated residuum. It was of such disintegrated materials, the product of rock decay, that the first soil of the region was composed. When, later in geological times, the terrestrial surfaces became clothed with vegetation, and generations of plants of greater or less luxuriance grew and perished in succession, organic acids taken up by the percolating ground waters greatly accelerated the processes of rock disintegration, and rapidly increased the depth of the assemblage of incoherent materials that, in popular speech, is called soil. The roots of the plants insinuating themselves into the cracks and crevices of the rocks and growing there, had the effect of forcing the rock masses apart and affording freer entrance to the agents of solution. Strains resulting from diurnal or seasonal alternations of temperature opened up new lines of successful attack that were immediately utilized by the agents of destruction. And thus the rocks slowly wasted away under the influences noted, and the insoluble residual products constituting the soil tended to increase in thickness. But another agent was at work, and it had the effect of reducing the thickness of the mantle of disintegrated material. If such materials could increase in thickness undisturbed, they would, in time, effectually protect the undecayed portions of the strata beneath from destructive influences, and thus put an end to further progress in rock disintegration. But the surface waters exercise mechanical effects as well as chemical, and so the loose surface materials were in part removed by erosion and transportation. By such removal the agents of solution and disintegration had fresh portions of the rocky strata brought within the sphere of their activity. Through the combined effects of disintegration, erosion and transportation, layer after layer of the original sediments covering Allamakee county has been stripped off and carried away. At the mouth of the Oneota

river the aggregate thickness of the beds so removed cannot be less than twelve hundred feet.

The amount of residual, insoluble matter in the rocks of Allamakee county, taking the sandstones, shales and limestones all together, would probably, according to observations made by McGee, exceed half the bulk of the original beds. Nowhere, however, is there found any very considerable thickness of residual detritus in the position in which it was produced. The average thickness on the divides and slopes probably does not exceed ten feet. For a short distance back from the Mississippi the recent changes in the base level of the drainage streams has led to the silting up of the valleys. Near the mouths of the rivers, therefore, we find superficial deposits with a thickness of forty, fifty or even sixty feet; but these are largely the result of transportation and redeposition; they are secondary and alluvial, not truly residual. It will be seen therefore that the present thin mantle of residual clays is but a small fraction of the entire product of rock decay which the region has suffered; and that the work of erosion and transportation has in the long run very nearly kept pace with the work of rock disintegration.

Geologists are indebted to Mr. McGee for the revival of the term "geest" to designate the residual products resulting from the disintegration of rocks in place. The geest of Allamakee county conforms to the rule observed everywhere else—that is, it varies in character and composition according to the nature of the underlying rocks. The most typical geest is found in those parts of the county underlain by the Oneota and the Trenton limestones. The decay of the Saint Croix and the Saint Peter formations produces a residual soil composed simply of incoherent sand.

The soils underlain by one or the other of the great limestone formations is a tenaceous, ferruginous clay, sometimes rich enough in ocher to constitute a fair grade of mineral paint, containing in its lower parts imperfectly decayed, highly corroded, iron-stained fragments of limestone, while scattered throughout its entire thickness are grains of sand, nodules of chert, silicified fossils and whatever else of an insoluble character was contained in the original beds. The geest derived

from the Oneota limestone may be studied to advantage at Waterville, while that from the Trenton may be seen at numerous points about Waukon. Although the two formations differ very greatly in lithological characters, there are no very obvious differences in their residual products. The limestone immediately underlying the geest, particularly in the Trenton area, is usually very much pitted and corroded, and iron-stained to a depth of eight or ten or even twenty feet, while the geest is found to have insinuated itself into all the pockets and fissures and irregular openings of every kind as far at least as there are signs of decay.

The geest, which by itself constitutes a very poor soil for agricultural purposes, is after all but one of the elements making up the superficial deposits of the county. Everywhere, at least in all places from which it has not been subsequently removed by erosion, there occurs the comparatively recent Pleistocene deposit called loess. The loess rests upon the geest and sometimes grades into it imperceptibly. It is thickest in the southwestern part of the county and becomes more scanty toward the northeast. The loess was derived chiefly from the drift that overspread the greater part of Iowa in the early part of the Pleistocene. It may be in part wind-driven dust carried from the dried verdureless surface of drift covered plains after the retreat of the glacial ice. Such plains existed only a few miles west of Allamakee county. In part the loess may be sediment deposited from turbid water. However it was carried, and however laid down, it differs from geest in being much less tenaceous, less ferruginous and less highly oxidized. A foundation of geest with a top dressing of loess makes almost the ideal soil, as the magificent crops of the region of which Waukon is the center, annually testify. When rains are excessive the water passes through the porous loess and leaves the surface not only in condition for easy cultivation, but for such absorption of gases and distribution of moisture as best contribute to the nourishment of plants. In seasons of drought the geest retains moisture which by capillary attraction is brought up within reach of the growing vegetation.

Geest and loess make up the upland soils of the county. The flood plains of the rivers, particularly along the Oneota and its tributaries, are occupied by a rich, mellow, alluvial soil of wonderful fertility. From the mouth of Bear Creek to the Mississippi the Oneota valley, during the spring and summer months, is one great hot bed in which varieties of corn that seldom ripen in ordinary situations north of Kansas or Missouri, make prodigious growth and easily attain full maturity before the advent of the usual autumn frosts. The alluvial deposits of the valley from the confluence of Bear Creek to the mouth of the Oneota seem even now to be increasing in thickness by periodic increments of loam, rich in organic matter, laid down during times when the river overflows its flood plain.

There is no drift, properly speaking, in Allamakee county. The loess is to a large extent a secondary product of the drift. In the southwestern townships there is more or less of overwash from the drift margin to the westward. Granitic bowlders having a diameter of from two to three feet have by some means been carried as far east as Makee township, and fragments of crystalline rocks of every size, from the dimensions of the largest bowlders observed down to the smallest pebbles, are strewn along the main valleys. Even Iron Hill, the highest point in the county, has a soil charged with numerous small pebbles of foreign origin. The high lands therefore as well as the valleys received some products of the drift that could only have been transported by moving water; but aside from the loess the drift products constitute a very inconsiderable portion of Allamakee soils.

In connection with the subject of superficial deposits mention should be made of certain comparatively recent accumulations of rather coarse materials, such as sand and gravel, that are found not only in the principal drainage valleys, but also occasionally in those of secondary importance. The materials in question are usually stratified. They may take the form of ridges, as, for example, the narrow ridge of stratified sand between Bear creek and the Oneota near the confluence of the two streams, or they may cling to the valley sides and produce well marked terraces. The valley of the Oneota affords the

best examples of such deposits. Their thickness, measured from the level of the flood plain to the flattened summit is from fifty to sixty feet. One of these deposits may be seen in a valley now carrying a stream of insignificant proportions, just west of Lansing. The accumulations under consideration may probably all be grouped under the name of postglacial terraces. They date doubtless from the time of rapid melting of the ice toward the close of the glacial period. The Oneota river at this time was somewhat exceptionally situated as compared with other streams of the county. The upper part of its drainage area was occupied by ice. Immense volumes of water, set free by melting, must have taxed the carrying capacity of its valley of erosion, and the amount of comminuted rock debris passing down to the Mississippi was limited only by the transporting power of the stream. In the eddies, and along the inner sides of the several curves of the winding valley, the suspended rock detritus was thrown down in large volume; and it is the mere shreds and remnants of such accumulations that now constitute the terraces under consideration.

Geological Structure.

DEFORMATIONS.

Allamakee county is traversed from southeast to northwest by what McGee has called the Snymagil anticlinal. The result is that many anomalies and surprises are met with in tracing the outcrops of strata from point to point along the sides of the intricate system of valleys that lie in the path of this fold. These anomalies furthermore have been rendered all the more puzzling by reason of the fact that the slopes of the sides of the anticline are in some places very gentle and at other places they are unexpectedly steep, while the phenomena are still further complicated by the development of small secondary folds at the points that have been subjected to the greatest amount of dynamic strain.

The greatest variation in the dip of the limbs of the folds occurs apparently on the northeast side of the axis, and the locality where the most pronounced anomalies occur, so far as

observed, lies three or four miles east of Waukon. For example, there are several points in the northeast quarter of section 35 in Makee township at which the contact of the Saint Peter with the Trenton is exposed having an elevation above sea level of about 1 200 feet, while less than half a mile to the northeast there is a series of exposures along the juncture of the two formations with the altitude 150 feet lower. The exposed layers of Trenton above the Saint Peter show a steep inclination to the northeast. On the opposite side of the crest the strata are for a mile or two nearly level and then dip to the southwest at the rate of about thirty-five feet to the mile.

There is evidently a well developed synclinal trough along the line marking the least altitude of the upper surface of the Saint Peter sandstone, for northeast of that line the strata rise for a short distance at the rate of seventy-five feet to the mile. Within about a mile and a half the dip changes again to normal.

The effects of the same anticlinal with its correlated synclinal on the northeast side of the axis are very marked in the neighborhood of Quandahl. The anticlinal axis lies a short distance to the southwest of Quandahl, and hence at the village all the strata dip strongly to the northeast. The south side of the valley of Bear creek is characterized by a horizon of springs that issue near the line of contact between the Oneota and the Saint Croix. Contrary to experience in parts of the county where the dip is normal, there are no springs on the north side of the valley. The strata retain their northeast dip until the bottom of the synclinal trough is reached. The position and direction of this trough would nearly coincide with a line projected from the northeast corner of section 18 through the center of section 19 in Waterloo township. Northeast of that line the dip is to the southwest. At first the rate is forty feet to the mile, but farther from the bottom of the fold the rate per mile is only about twelve feet.

Many other flexures and departures from the ordinary dip were noted, but the purpose for which the survey was prosecuted precluded such detailed investigation as would be necessary to determine the direction of the several folds, the amount

of departure from normal dip, or the extent of territory involved in each case. It is enough to say that the several strata do not lie in planes inclined at a uniform angle, but that they are deformed by flexion and crumpling to an extent hitherto unsuspected. Foldings in Iowa strata may yet have an economic significance, although no such claim can be made for those of Allamakee county. Successful oil and gas wells are as a rule those only that are drilled along the crests of anticlinal folds, and folds in strata that lie higher in the geologic series than those of Allamakee may some time be proved to be productive sources of both oil and gas.

EXPLANATION OF PLATE.

In plate one is represented a geological section along a line drawn from New Albin to Postville. The section should be read from left to right, beginning at the top of the plate. The numbers refer to the different formations as follows:

1, 2 and 3. SAINT CROIX SANDSTONE.
- 2. Beds equivalent to the Lawrence limestone of Minnesota.
- 3. Beds equivalent to the Jordan sandstone of Minnesota.

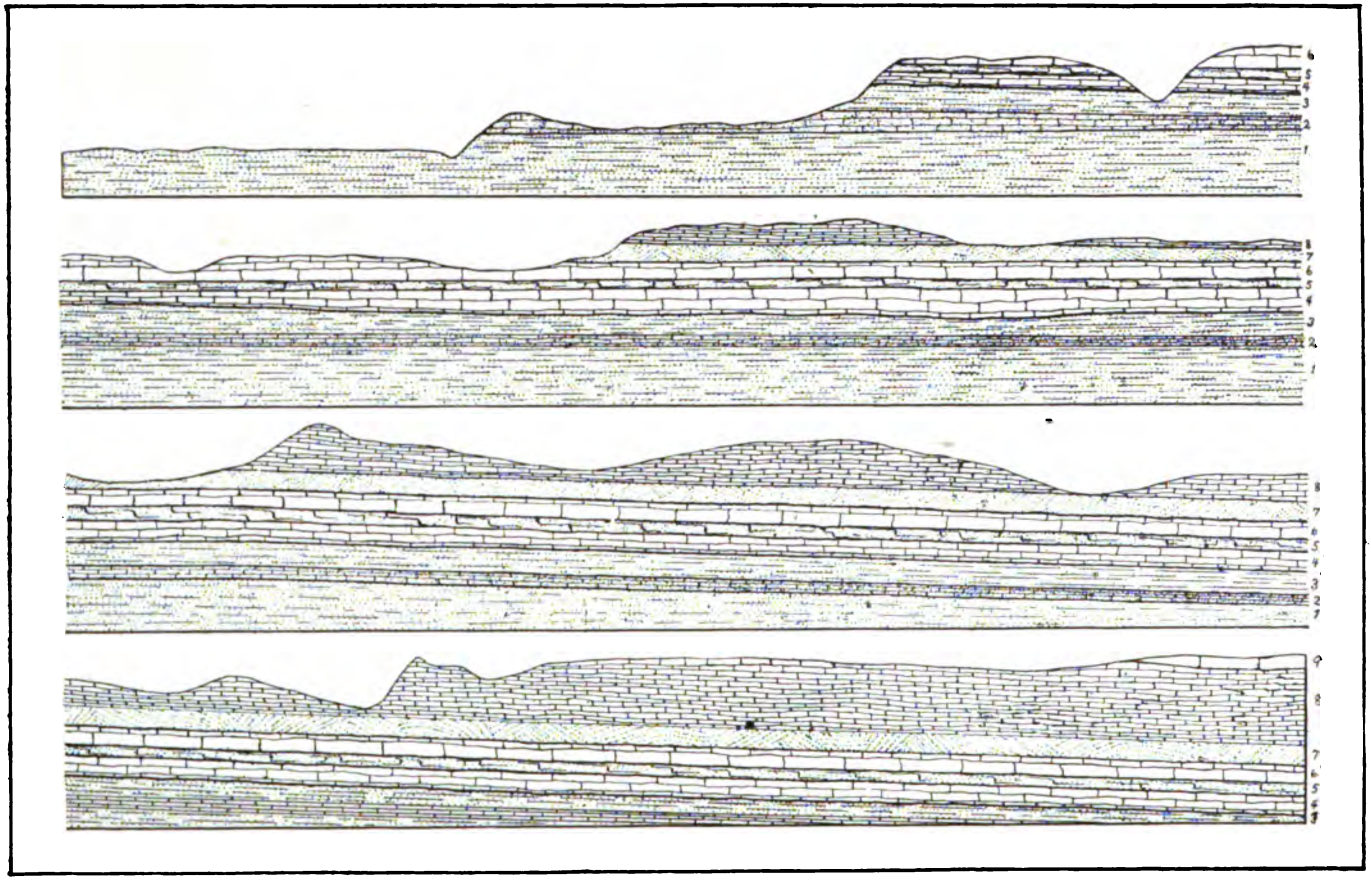
4, 5 and 6. ONEOTA LIMESTONE.
- 5. Intercalated sandstone beds representing the New Richmond sandstone of Minnesota.
- 6. Beds equivalent to the Shakopee limestone of Minnesota.

7. SAINT PETER SANDSTONE.
8. TRENTON LIMESTONE.
9. GALENA LIMESTONE.

ECONOMIC PRODUCTS.

BUILDING STONES.

All the formations of indurated rocks in Allamakee county afford quarry stones that have been employed for building purposes. Some of these quarry products would be ranked as of rather inferior quality, but on the other hand some of the best building stone to be found within the limits of the state occurs in Allamakee.



GEOLOGICAL CROSS-SECTION IN ALLAMAKEE COUNTY.

Saint Croix Sandstone.—As already noted there are beds in the Saint Croix sandstone at Lansing, from 100 to 125 feet above the level of the river, that have been quarried for building purposes. The quarry beds lie beneath the yellowish, shaly, somewhat calcareous, trilobite-bearing layers that are the equivalent of the Saint Lawrence limestone of the geologists of Minnesota. The sand of which they are chiefly composed is cemented with calcium carbonate, and the fissures that intersect the strata have their sides coated with a thin crust of stalagmite. The same beds are exposed at numerous points west of Lansing and in the Oneota valley. The material they afford is fit only for the commonest uses. In general it may be said that the quarries in the Saint Croix sandstone have no commercial value.

Oneota Limestone.—A few feet above the contact of the Saint Croix with the Oneota the dolomite, for a thickness of about thirty feet, becomes evenly and regularly bedded, the rock is fine grained, and the layers vary from three to thirty-six inches in thickness. The value, however, of this portion of the formation as a source of quarry stone is not the same in all parts of the county. At New Albin, Lansing, Harpers Ferry, and generally in the eastern portion, the beds referred to are worked more or less extensively, but the product would rank only as of medium grade. In the northwestern part of the county the beds at the same geological level are finer grained, more compact, and are capable of affording material for fine masonry unexcelled by any limestone in the Mississippi valley. The region in which the quarry stone of the Oneota is best developed lies around Dorchester. Topographically it is very rough, and at present is inaccessible except by wagon. Quarries have not been worked except on a very small scale. Quarrying has been done, however, somewhat extensively by the natural agencies of erosion. Great blocks thus detached and precipitated to the plain were observed at a number of points. In some cases the blocks have split into slabs of varying thickness, with smooth, parallel faces ten or fifteen feet in length and almost as many in width. The undecayed condition of these masses after long exposure under most unfavorable conditions demonstrates their

durability. There are many natural exposures affording an opportunity to observe the quality of the quarry stone which the Oneota will some time furnish, among which may be mentioned those near the northeast corner of section 16 in Hanover township (Tp. 99 N., R. VI W.), those in the southwest quarter of section 10, and in the northwest quarter of section 13 in Waterloo township (Tp. 100 N., R. VI W.), and others in section 18 of Union City township (Tp. 100 N., R. VI W.). (Figure 7).

Figure 7. Natural exposure of Oneota limestone northeast of Dorchester.

With only a few exceptions, the Oneota limestone above the beds described occurs in massive layers not easily quarried, and the rock is too coarse and vesicular to be of any value except for the roughest kinds of masonry. Near the summit of the formation, as already described, occurs the intercalated beds of sandstone that represent the New Richmond sandstone of Minnesota and Wisconsin. The sand grains are cemented by secondarily deposited silica which gives to these beds an important element of durability. The beds break readily into prismatic blocks. The stone would be valuable were it not that the aggregate thickness of the beds is too small to justify their being worked except by the simplest and most inexpensive methods

They may from time to time supply local needs on a small scale.

The Saint Peter Sandstone is in general an uncemented mass of quartzose sand. It is too inchoherent as a rule to be considered as a building stone. Nevertheless there are a few exposures in which silica deposited from solution, or iron oxide carried into the mass by infiltration from above, has consolidated the beds sufficiently to justify their use for building purposes. Where iron oxide is the cementing agent the beds are curiously streaked and mottled, bright red and nearly pure white patches being intermingled in ways most fantastic and irregular. Such an exposure is found near the middle of the south half of section 27 in Makee township (Tp. 98 N., R. VI W.), about three miles east of Waukon. An exposure affording an illustration of Saint Peter sandstone consolidated by siliceous cement occurs in the Nw. ¼, Sw. qr., sec. 14, Tp. 96 N., R. V W., where the sandstone stands in vertical cliffs thirty or forty feet in height, and in some cases weathers into angular massive blocks so piled together as to resemble titanic masonry. There are numerous other similar exposures, but those mentioned will serve respectively as types of their kind.

Trenton Limestone.—The quarry stone afforded by the Trenton limestone is so variable in quality as to make it difficult to characterize it. A small proportion of it is very excellent, a large portion is exceedingly poor and unreliable. At no place can a quarry be opened that will afford material uniformly good. In an exposure of fifteen or twenty feet there may be a single layer, eight or ten inches in thickness, that has the qualities desired in a building stone, while all the rest is worthless. Above the thin shale bed that rests on the Saint Peter, and which marks everywhere the base of the Trenton, there are from fifteen to twenty-five feet of rather thick-bedded, yellowish limestone resembling dolomite—the Lower Buff beds of the Wisconsin geologists. These beds are exposed about two miles below Waukon in the valley of Paint creek. They are seen on the land of John Fossum in Prairie Creek township (Tp. 97 N., R. IV W., sec. 6, Sw. qr.). The exposure affording the most massive beds was seen near the southwest corner of the Se. ¼,

Sw. qr., sec. 10., Tp. 96 N., R. V W. Here the layers are compact, more than two feet in thickness, and would furnish good material for bridge piers and similar heavy work. While the "Lower Buff beds" of the Trenton have the desired element of durabiliy their texture disqualifies them for use except in any but the rougher kinds of masonry.

About seventy-five feet above the base of the Trenton there are beds that are quarried somewhat extensively near Waukon as well as at other points in the portions of the county covered by this formation, The layers here are fine grained, dark gray or slate in color; but they have the disadvantage of being thin, and many of them break up, first along the planes of lamination and then into small angular pieces, on exposure to the weather. With proper selection excellent building material may be obtained, but it often necessitates the handling and discarding of an immense amount of rubbish. Quarries are also worked on a small scale north of Postville within a hundred feet of the top of the formation, but it may be said that, as a whole, the Trenton limestone of Allamakee county will never be commercially important as a source of building stone.

The Galena Limestone of Allamakee county affords no quarry stone, although only a short distance south of the Clayton-Allamakee line the towns of Monona and Luana are supplied with excellent material for ordinary local needs from this formation.

ORNAMENTAL STONES.

Certain compact layers of the Trenton limestone, made up largely of fragments of brachiopods and bryozoans cemented with what was originally fine calcareous mud, are capable of taking a fine polish and have been used to a limited extent in making table tops, mantles, fancy paper weights and other objects for indoor decoration, in the manufacture of which marble may be employed. All the pores and interstices of the original rock and its contained fossils have been filled with infiltrated calcite. There is usually quite a difference in the shades and gradations of color between the ground mass and the embedded fossils; but on the whole the effect is very pleasing and it is quite possible that the manufacture of polished

stone for decorative purposes may become an important industry. The beds most suitable for grinding and polishing occur as rather thin layers of very fossiliferous limestone embedded in blue clay. They begin about forty feet above the base of the formation, and occur, sometimes at rather short intervals, through a thickness of twenty-five or thirty feet. Good exposures may be found in the washes and gullies on section 8, and also near the center of section 19, of Makee township. The same beds are exposed about the middle of the east line of section 18 in Waterloo township. Indeed, owing to the remarkable topography of the county, there is scarcely a section occupied by Trenton limestone that does not afford exposures of the fosssiliferous slabs under consideration.

LIMES.

Allamakee county abounds in limestone, and lime has been made on a small scale at a great many localities. The best lime is that made from the Oneota dolomite. The massive vesicular, most completely dolomitized beds near the middle of the formation, are best adapted to the manufacture of lime. It is from these that the Waterville lime is made, the work of lime burning having been carried on here for several years by Mr. O. C. Frok. Six or seven kilns are burned annually and there are from three to four hundred bushels in each kiln. The quality of the lime is good and a much larger product would find a ready market. Lime made from the Trenton limestone is regarded with little favor. A few small, hastily constructed kilns have been built within the Trenton area to supply immediate local needs, but none of them have been operated continuously for any considerable length of time. The Oneota of Allamakee county is capable of affording material for the manufacture of a high grade of lime in quantities sufficient to supply an empire.

HYDRAULIC LIME AND CEMENT.

Limestones containing from ten to twenty per cent of clay may furnish a quality of lime that has the property of setting under water. If the limestone is magnesian, that is, if part of

the calcium carbonate has been replaced by magnesium carbonate, a smaller amount of clay will be sufficient to impart hydraulic properties to the lime. Many portions of the Trenton limestone are more or less argillaceous, and samples might be easily selected that, on analysis, would show the proper admixture of silica, alumina, iron, and calcium and magnesium carbonates to make a good water lime, but the difficulty would be in finding a sufficiently large body of limestone of uniform quality at any one place to justify the outlay necessary to begin the work of manufacturing. One exception may be made to this statement. The "Lower Buff beds," that rest on the basal shale of the Trenton, have a thickness of from fifteen to twenty feet; they are fairly uniform in quality; if one may judge from chemical analysis alone, these beds would furnish a good hydraulic lime. Silica, alumina, iron, and magnesium carbonate are present in essentially the same proportions as in rocks from which hydraulic cement has successfully been made.

CLAYS.

The clays of Allamakee county may be divided into three divisions, namely, loess, residual clays or geest, and clays of primary origin, or shales, that were laid down as part of the original sedimentary terrains. Some phases of the loess in the southwestern part of the county are suitable for the manufacture of ordinary brick. It is seldom that a sufficient body of geest is present at any given point to make it commercially important. The clays deposited as part of the original sediments are found in all the formations except the Saint Peter sandstone. Some are of excellent quality and well adapted to the manufacture of the better grades of pottery. Most of them are of little importance on account of the fact that the beds are too thin to support manufactures on any profitable scale.

In the Sw. ¼, Ne. qr., sec. 9, Tp. 100 N., R. IV W., there is exposed in a road cutting a bed of light colored shale belonging to the Saint Croix sandstone. The geological position of the bed is about two hundred feet below the summit of the formation. A thin bed of gritty shale occurs near the top of

the Oneota, but the Saint Croix and Oneota shales, so far as observed, do not require further notice.

Clays, valuable so far as quality is concerned, but often commercially unimportant by reason of the thinness of the deposits, occur at different levels in the Trenton limestone. At the very base of the Trenton, resting directly on the Saint Peter sandstone, is a bed of clay about six feet in thickness. At many of its exposures this clay is of very excellent quality. It is overlain by the rather massive layers of the "Lower Buff beds" of the Trenton, and could therefore be easily mined to a limited extent. By a proper selection of localities material for the manufacture of pottery, paving brick, tile and a number of other clay products might easily be obtained. The exposures of this basal shale are very numerous. It may be seen at all points along the exceedingly sinuous line that marks the contact of the Saint Peter with the Trenton. It is exposed on the road leading north from Waukon on both sides of Village creek. In the valley of Paint creek, about two miles below Waukon, it appears at the surface. The best example of this clay for use in making pottery was seen in the Sw. ¼, Sw. qr., sec. 8, Tp. 98 N., R. V W., in the valley of a tributary of Silver creek. But the exposures are too numerous to be mentioned in detail. This clay bed is one of the most persistent members of the Trenton and may be studied equally well within a short distance of the Iowa-Minnesota line in Waterloo township, near the southern limit of the county in Linton township, or at the eastern extremity of the narrow tongue of Trenton, that lies along the summit of the Lansing ridge (Tp. 99 N., R. IV W., sec. 29, Se. qr., Se. ¼).

Another shale-bearing horizon begins about forty feet above the base of the Trenton and continues through a thickness of thirty feet, but while some of the clay is of superior quality and suited to a variety of purposes, the shale lies in rather thin beds interstratified with highly fossiliferous limestone. Some of the clay beds are rendered useless by reason of the additional fact that they contain fossil corals, bryozoans, and calcareous nodules in considerable abundance and more or less evenly distributed.

A third clay-bearing horizon in the Trenton occurs near the summit of the formation. This is perhaps the most important commercially, for the body of workable clay is in some cases from ten to twenty feet in thickness. Exposures of the upper clays are found in the southeast quarter of section 20 of Post township, about two miles north of Postville, and other exposures occur wherever the undulating surface intersects this same geological plane in the hillsides south of Yellow river. This clay is not worked in Allamakee, but at Clermont in Fayette county it has been utilized for many years in the manufacture of drain tile and cream-colored brick of excellent quality.

The only clay products at present manufactured in the county are ordinary building brick made from the loess and geest at Waukon. Messrs. A. N. and N. H. Peck have operated a brick yard at this point for a number of years. For the last ten years the average annual output has been about 300,000; in 1894 the product reached about 600,000. The bricks are made with a two-horse power "Quaker" machine having a daily capacity of 20,000. The machine, however, is not worked to its full capacity. With steam power and a force of seven men and two boys the output while operating is only about 10,000 daily.

SANDS.

Glass Sand.—Sands suitable for the manufacture of window glass, plate glass, table glassware and the like are found abundantly in the Saint Peter sandstone. It is true that the larger part of this formation is streaked and otherwise stained with iron oxide, but certain portions of the beds, capable of supplying many carloads annually for an indefinite period, are pure and white as pulverized rock crystal, and well adapted to the manufacture of a high grade of glass. The pure white quartzose material seen in the sand pit on the farm of Mr. James Dougherty (Tp. 99 N., R. V W., Se. qr., Se. ¼) affords a good illustration of the quality of the glass sands that occur at numerous points throughout this county. It is characteristic of the whiter portions of the Saint Peter sandstone that they are so loose and incoherent that they may be excavated with a shovel almost as easily as a modern bed of dry river sand.

Building Sand.—Both the Saint Croix and the Saint Peter sandstones are in places easily excavated, and the material has been used as building sand. The supply is unlimited and the distribution so general that very few portions of the county are very far removed from available sand pits. The sand from the formations named is usually too fine, when used alone, to make the best grade of mortar; but when mixed with a certain proportion of coarse river sand it serves an excellent purpose.

IRON.

Hæmatite and Limonite.—The geest resulting from the decay of the Trenton and Oneota limestones is rich in iron oxide. It also often contains nodules and masses of impure clayey limon-

Figure 8. Iron Ore Pit at Iron Hill.

ite or hæmatite; but in general the amount of iron is too small to have any commercial significance. There are, however, two or three points within the Trenton area at which ore, partly true hæmatite and partly the hydrated form called limonite, occurs in considerable amount, and may some time be worked at a profit. The ore beds are on the highest points near Waukon,

the principal body occurring at Iron hill in section 17 of Makee township (Tp. 98 N., R. V W). Ore here exists in the form of large concretionary boulder-like masses mixed with ocherous clay. Some of the concretions disintegrate more or less, so that the interstices are often filled with a granular ocher, consisting of hæmatite with some admixture of clay. This could be easily separated by washing and would serve excellently for mineral paint. Pits have been opened at various points to test the quality and depth of the deposit, the results indicating that the ore beds have a thickness of from twenty-five to forty feet.

Another body of ore occurring in Makee township is found on a very prominent outlook in the southeast quarter of section 27. Ore also is found in Paint Creek township, near the northwest corner of section 6. The ore body at Iron hill is, however, the one that is most likely to become commercially valuable.

As already noted the beds of ore that have attracted attention all lie on high points—the highest, indeed, in the entire county. They are all underlain by from fifty to a hundred feet of Trenton limestone, with the exception that, on the south side of Iron hill, the ore comes down so as partly to overlap the Saint Peter sandstone.*

At all points mentioned the ore is a comparatively thin veneer lying over the hill top. The general trend of the ore-capped ridges is east and west. The relation of the ore to the ridge is unsymmetrical, for the thickest part of the body is south of the summit, and the distance below the summit to which it descends is greater on the southern than on the northern slopes.

Like the geest the hæmatite was originally a constituent part of the sedimentary strata that have disappeared from the region through the combined action of erosion and the agents concerned in producing rock disintegration and decay. Unlike

*NOTE.—In the *Pleistocene History of Northeastern Iowa*, *Eleventh Annual Report of the United States Geological Survey*, p. 548, McGee speaks of the iron ore three miles northeast of Waukon as if it were a part of the residuum resulting from the decomposition of Oneota limestone. At all the points where these deposits occur the Oneota terrain lies deeply buried out of sight, more than a hundred feet below the level of the ore beds, and could have contributed nothing to the residual products resting on the surface,

the geest, however, it is not a true residual product, but is rather a result of secondary processes whereby the ferruginous material normally present in the geest has been collected and massed together at a few favored points. Iron hill, the highest eminence in the county, has by far the largest body of ore. The amounts present at the other points observed are less; and the least important ore body is on a hill that is lower than either of the other two. The relation is doubtless largely accidental, but at first sight there would seem to be some connection between altitude and the conditions favoring the concentration of the hæmatite. A possible explanation of the facts observed will be given further on.

That the ore beds here discussed are not primary products of rock decay in place, but that some secondary process of concentration must be taken into account in explaining their origin, will be obvious from a few considerations. First the thickness of the strata removed by solution and erosion from the summit of Iron hill is probably about 800 feet. It cannot, on any reasonable supposition, be more than 1,000 feet. The position of the Niagara escarpment west of the Turkey river, as well as the position of the Niagara outlier at Williams quarry in the northeastern corner of Fayette county, would indicate that the whole region, probably as far as New Albin to the northeast, was originally overlain by the Niagara limestone. Making a liberal estimate of the thickness of the original strata, the beds removed from the top of Iron hill since the sea retreated from Allamakee county would stand as follows:

	FEET.
Niagara limestone	250
Maquoketa shales	100
Galena limestone	250
Trenton limestone	200
Total	800

These estimates are all probably somewhat too large, but allowing them to stand, and allowing, which is quite improbable, that the sea stood over the region until two hundred feet of Devonian strata had been deposited, we would then have a

thousand feet of sediments removed in bringing the surface down to the level of the highest divides. Now the amount of iron oxide in a thousand feet of strata is altogether insufficient to account for such a body of hæmatite as occurs on Iron hill, even supposing that none of it had been carried away by the streamlets that have ever been at work removing the clays and all other constituents of the geest. According to analyses made by Whitney, Emory and others, the amount of iron oxide that could possibly be furnished by the Niagara, Maquoketa, Galena and Trenton beds would be less than one per cent of the mass. In one thousand feet of such strata the ferruginous constituent might be sufficient, let us say, to make a layer of hæmatite ten feet in thickness, provided none of it were lost in connection with the processes of erosion during the long ages requisite to bring about the solution and decay of such a volume of sediments. Now in the first place the main body of hæmatite is in places more than three times ten feet in thickness, while in the second place it is highly improbable, indeed it is practically impossible, that the iron oxide alone, of all the residual products, should escape the destructive and translative effects of flowing surface waters. Elsewhere the amount of iron oxide in the geest is but a mere fraction of that which was present in the beds of sediments that have suffered decay. The adjacent portions of the county, with their ferruginous geest, illustrate the ordinary conditions of the residual products, such residua being the normal resultant of the combined action of all the dynamic agents that have been at work on the strata of the region since first it was elevated above the level of the sea. The hæmatite of Iron hill is indicative of some unusual activities and conditions. What these activities and conditions were cannot now be absolutely demonstrated; but in the absence of positive knowledge we are justified in relying on legitimate inference, and there are certain possibilities that may appropriately be considered. By processes well known to the chemist and mineralogist iron oxide is leached out of soils and concentrated in bogs and marshes as a result of chemical reactions taking place between decomposing organic matter—usually vegetable tissues—and the ferric oxide in contact with which

decomposition takes place. The processes have been so well set forth by so many writers that the details need not be here repeated.

Ever since the process of rock decay began over Allamakee county the geest has been highly ferruginous and capable of serving, as a source of supply, to agents concerned in the accumulation of iron ore. During the greater part of the time since the Carboniferous period the surface of the county has been covered with a rank growth of vegetation, mostly aboreal, which, falling and decaying in countless successive generations, furnished a second essential for ore concentration. An imperfectly drained area, or marsh, of sufficient extent, constant as to position for a considerable period of time, and receiving the ground water from many square miles of adjacent territory that rises in very gentle slopes, is the only requisite condition remaining. Such a marsh we may assume existed in the latitude and longitude of Iron hill at some time during the long periods required for the removal of the eight hundred feet of sediments that have been stripped off from the whole territory we are discussing above the level of the summit on which the ore now lies. The diagram (Fig. 9), shows the probable succession of conditions which have brought about the present relation of ore to topographic forms. The beds, *d–d*, are the Niagara, Maquoketa, Galena and Trenton strata that have been bodily removed from many hundreds of square miles by the slow processes of solution and mechanical erosion. The line *e–e*, is the profile through the supposed marsh into which the iron was carried after being reduced to the soluble condition through the agency of decomposing vegetable matter. In this marsh the iron was reoxidized and precipitated in the condition in which we now find it. The accumulated ore served to protect the underlying strata, but solution and erosion proceeded to reduce the level of all the surrounding area, until finally the marsh was drained.

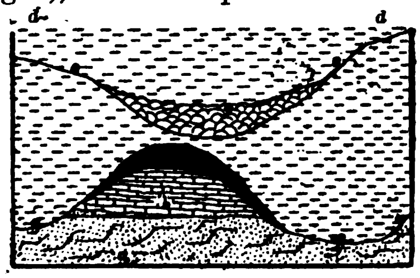


Figure 9. Ideal Section through Iron Hill.

Even after the draining of the marsh the degradation of the adjacent territory proceeded without interruption, while the protective deposit of iron ore effectually preserved the small area it covered. In time the profile was changed to that represented by *g–g*. The bed *a*, represents Saint Peter sandstone, *b* the unremoved portion of the Trenton, and *c* the body of ore that accumulated in the long vanished marsh. At *f* is the channel and valley of Village creek, cut down into the Saint Peter sandstone. The fact that the ore is more abundant on the southern than on the northern sides of the hills is doubtless due to the fact that southward facing slopes recede more rapidly than others, being more exposed to attacks by agents of erosion. At present the southern exposures are destitute of forest growth, while slopes facing to the north are clothed with trees and other protective vegetation. Thawing and freezing and other alternations of temperature affect the hill sides that look southward more seriously than the others, and so the destructive forces are eating under the protective cap of iron ore more rapidly on the southern than on the northern side, with the effect that the ore body is no longer symmetrical with reference to the hill.

Professor G. E. Patrick, chemist of the Survey, reports upon three fairly average samples of Allamakee county ores as follows:

"Sample No. 275—Iron ore from Iron Hill, Allamakee county.

Iron, 54.32 per cent.
Sulphur, none.
Phosphorus, 1.30.

The phosphorous is in the form of phosphate: $P_2 O_5$=2.97 per cent.
The ore is Limonite or Brown Hæmatite (hydrated sesqui-oxide of iron.)"

"Sample No. 278—Iron ore from near Waukon. (Iron hill.)

Iron, 66.920 per cent.
Sulphur, .047.
Phosphorous, .503.

The phosphorous is in the form of phosphate: $P_2 O_5$=1.15 per cent.
The ore is Hæmatite (anhydrons sesqui-oxide of iron)."

"Sample No. 279—Iron ore from southeast of Waukon. (From section 6 of Paint Creek township.)

Iron, 58.680 per cent.
Sulphur, none.
Phosphorous, 1.15.

The phosphorous is in the form of phosphate: $P_2 O_5$=.262 per cent.
The ore is Limonite or Brown Hæmatite (hydrated sesqui-oxide of iron)."

At present the nearest shipping point to Iron Hill is Waukon, which would necessitate a wagon haul of three miles. This fact, coupled with conditions that render iron properties of the highest grade practically valueless, makes it now impossible to handle these ores with any profit.

MINERAL PAINT.

The residual product, or geest, resulting from the decay of the Trenton and Oneota limestone is everywhere highly charged with oxide of iron. The rich color which the iron imparts to the clay has led in some places to the popular belief that the whole body of local geest is practically a deposit of mineral paint. While in general the geest contains too much clay to justify the belief referred to, it is yet true that many somewhat limited portions of it are sufficiently ocherous to make it suitable for use in painting barns and other structures where efficiency and durability are the chief qualities desired. Paint creek receives its name from the paint-like character of the red ocherous geest that abounds at different points along its valley, notably near Waterville and Waukon. The chief source of material for paint in the county and the one that may be worked for this purpose with reasonable prospects of profit, is the red, powdery, interstitial filling between the concretions of hæmatite on Iron hill. At all events this source might be operated with profit if there was any paying market for the iron ore.

LEAD.

Galena or Galenite.—Ever since the settlement of the county there has been a prevalent impression that large bodies of lead ore exist in the Oneota limestone and only await discovery to confer undertermined wealth on the fortunate prospector. There is also a tradition that the Indians were familiar with the location of some of these ore bodies, and were in the habit of resorting to them periodically to supply themselves with lead. While is is true that the Oneota, like other great beds of dolomite, is a lead-bearing rock, it may be said at once that it can not be counted among the important sources of supply for this mineral.

More or less of galena of very excellent quality may be found in all the valleys cut in the Oneota limestone. In eroding the valleys the mineral was weathered out of pockets in the dolomite. Pockets and crevices containing galena are often met with in working quarries in the formation. Some of these have been brought to light by systematic prospecting, but with one exception the mineral has not been found in sufficient quantities to pay the expense of mining it. With the single known exception referred to the galena of the Oneota occurs in small pockets or fissures, a few inches wide, and at most from a few feet to a yard or two in length. There are no regular crevices, and the prospector finds after penetrating a short distance from the face of the bluff that the rock around the mineral bearing cavities is solid and not decomposed by weathering. The work of mining, therefore, is difficult and the reward meager and uncertain.

In the valley of Mineral creek, a small stream that enters the Oneota nearly opposite the mouth of Bear creek (Figure 10),

Figure 10. Canyon and bluffs of the Oneota river at the mouth of Mineral creek.

mining was prosecuted with a great deal of vigor a number of years ago. About a hundred thousand pounds of mineral, it is claimed, were taken out, the town of New Galena was built, and there were hopes that an important mining center was about to be developed. But the absence of true crevices that could be followed with ease and certainity, the hardness of the

undecayed rock and consequent difficulty of mining, and the small size of the mineral bodies when they were discovered, led to discouragement and general abandonment of the enterprise. The town of New Galena has disappeared and with it have gone most of the miners that came into the picturesque little valley in search of fortune; but a few hopeful prospectors remain, and, undeterred by the results of past efforts, continue to burrow in the hillsides in the hope always that to-day will certainly bring better luck than any of the days that have thus far come and gone. There is enough mineral to make the prospect seem good and to keep hope fully alive, but never enough adequately to pay for the labor and expense involved in finding it. In the aggregate the Oneota limestone doubtless holds a large amount of lead ore, but past experience offers little encouragement to men to abandon other industries and spend time and money in the search for paying bodies of such ore in this particular formation.

The mines of the Lansing Mining and Smelting Company constitute the exception already noted. These are located about six miles northwest of Lansing (Tp. 99 N., R. IV W., sec. 10, Nw. qr., E. ½). They were discovered by Captain J. M. Turner who is now serving as superintendent of the mining company. The ore occurs in a north and south crevice that has been prospected and found to contain mineral in paying quantities for a distance of 1,200 feet. The vertical dimensions of the crevice are not known, but are not less than seventy-five feet. The sheet of mineral is about three inches in thickness, but the crevice, since the lead ore was deposited, has been widened by the decay of the wall rock, and the space thus added is filled with a residual product that is practically the same as geest, namely, ferruginous clay with partly decomposed nodules of chert. The ore, when first deposited, was evidently the lead sulphide, but the ground waters carrying carbon dioxide and organic acids have largely decomposed the sulphide and changed it superficially to lead carbonate. It is probable that the lead was deposited in the crevice early in geological time, certainly not later than the earlier Cenozoic, for everything about the wall rock, the ore body itself, and the residual

material filling the space that has been added through the effects of agents of decomposition and decay, all indicate the lapse of long periods of time since the galena was collected from the surrounding mass of dolomite and deposited in what was at the time a very narrow crevice.

Captain Turner is confident that the Oneota limestone contains other crevices as productive as the one on which his company is now operating; and there is no reason to doubt the correctness of his position except the fact that this is the only true lead-bearing crevice thus far found in this formation. Others probably will be found in time, but thus far the region adjacent to the mine under consideration has not been very thoroughly prospected.

The decomposition of the wall rock and widening of the crevice makes it possible to follow and remove the sheet of ore with little necessity for blasting. The vertical position of the crevice renders little timbering necessary, and whatever timbers are needed are readily supplied by forests on adjacent portions of the company's property. No pumping is required in operating the mine, for the Oneota limestone is singularly free from underground channels; the nearest water-bearing horizon is that which lies about a hundred feet below the upper limit of the Saint Croix sandstone. The mine, therefore, is dry, the work being in no way impeded by the presence of water. In June, 1893, a hundred tons of ore had been taken out and were lying on the dumps ready for shipment. A letter from Hon. James H. Trewin, president of the mining company, states that during the winter of 1893–4 the mines were worked constantly, employing ten men, and that about 250,000 pounds of ore were raised. The machinery for raising the ore is the simple windlass operated by hand power. The total amount of ore mined and prepared for market up to December, 1894, was 500,000 pounds, and the value of the output at present market rates is about $10,000.

While the Oneota limestone is the lead-producing, and, in general, the lead-bearing rock of Allamakee county, some ore bodies are occasionally found in the underlying Saint Croix sandstone. The Saint Croix lead ore was doubtless deposited

by descending waters that became charged with salts of lead while passing through the Oneota limestone and reached the Saint Croix before the sulphide was precipitated. Concerning one of these deposits very recently worked on the Lansing company's property, Mr. Trewin writes: "We took several thousand pounds from the Potsdam (Saint Croix) sandstone, but there does not seem to be much yield in that formation." The ore body of the Saint Croix, referred to by Mr. Trewin, lay in a fissure in the sandstone immediately beneath the lead-bearing crevice of the Oneota from which the Lansing Mining and Smelting Company have taken practically all the ore thus far produced. It occurred at the north end of the mine, where a ravine cuts transversely to the crevice, and all the ore contained in the sandstone was found within a hundred feet of the face of the bluff.

Analyses made by Professor G. E. Patrick show that the lead ores of Allamakee county, like those generally of the Upper Mississippi Lead Region, contain little or no silver. A sample from the Lansing company's mine, quite thoroughly coated externally with carbonate, contained 77.58 per cent of lead, while a specimen of pure sulphide from the site of the old mines near New Galena, analyzed 86.6 per cent.

ZINC.

Zinc carbonate (smithsonite) occurs occasionally in the residual detritus at the foot of cliffs of Oneota limestone. No bodies of this ore were seen in place, but there is no doubt that like the lead ore, it was derived by weathering from pockets and openings in the dolomite. A sample from Mineral creek analyzed by Professor Patrick, showed 46.08 per cent of metalic zinc.

WATER POWERS.

Allamakee county is generously supplied with cascades and with streams having channels descending at a comparatively high angle, so that water powers in large numbers, with head ranging from ten to ninety feet, might easily be obtained. Along the head waters of the streams that are tributary to the main drainage courses, the channels are yet far from being cut

down to base level, and it is upon such streams that water powers might be obtained with very little labor. Springs with sufficient volume of water to make them important as a source of power, issue at many points from the sides of bluffs, and the resulting streams fall in a series of cascades sometimes as much as a hundred feet in a comparatively short distance. The cascades at Devil's Den (figure 11) and at Pinney's spring (figure 12)

Figure 11. The waterfall at "Devil's Den."

have already been described, and are typical of what occurs at scores of localities within the county. But little has yet been done in utilizing the numberless sources of energy with which the county is so bountifully provided, but the time is certainly coming when a wider application of electricity to domestic and commercial uses will make all the possible water powers more valuable to the county than beds of coal.

Mr. J. G. Ratcliffe has compiled the following table showing the water power in use in Allamakee county in 1893.

NAME OF MILL.	STREAM ON WHICH LOCATED.	NAME OF OWNER.	POST-OFFICE.	KIND OF MILL.	APPROXIMATE FALL IN FEET.	APPROXIMATE HORSE POWER.	LOCATION.
Myron	Yellow river	Abram Hart	Postville	Grist	14	15	Sec. 3, Post Tp.
Manchester	Yellow river			Grist	10	12	Sec. 6, Franklin Tp.
Forest	Yellow river	Wm. Werham	Forest Mills	Grist and saw	12	18	Sec. 5, Franklin Tp.
Volney	Yellow river	Aug'st Tangaman	Volney	Grist and saw	10	20	Sec. 13, Franklin Tp.
Buckland	Yellow river	E. L. Cahoon	Buckland	Grist and saw	10	15	Sec. 16, Linton Tp.
Ion	Yellow river	Doehler & Kean	Ion	Grist	8	16	Sec. 24, Fairview Tp.
Waterville	Paint creek	V. H. Stevens	Waterville	Grist and saw	14	15	Sec. 22, Paint C. Tp.
Bluff Springs	Paint, creek	Michael Haas	Waterville	Grist and saw	10	10	Sec. 31, Taylor Tp.
Eagle	Village creek	Alex. Deramore	Village Creek	Grist	15	15	Sec. 14, Center Tp.
Union	Village creek	August Doehler	Village Creek	Grist	16	20	Sec. 13, Center Tp.
Capoli	Village creek	Joseph Doehler	Village Creek	Grist	4	8	Sec. 18, LaFayette Tp.
Woolen	Village creek	C. O. Howard	Waukon	Woolen fact'y	17	25	Sec. 18, LaFayette Tp.
Centennial	Village creek	Fred Doehler	Village Creek	Grist	7	15	Sec. 7, LaFayette Tp.
Kepler's	Lansing creek	——— Kepler	Lansing	Grist	14	15	Sec. 30, Lansing Tp.
Haney's	Lansing creek	Peter Larson	Lansing	Grist	18	15	Sec. 30, Lansing Tp.
Harper's Fe'y	Bulger's creek		Harper's Fe'y	Grist	15	.8	Sec. 23, Lansing Tp.
Hirt's	French creek	Hirt estate	French Creek	Grist	12	12	Sec. 11, French C. Tp.
MacMillan's	French creek	C. MacMillan	French Creek	Grist	15	16	Sec. 2, French C. Tp.
Dorchester	Waterloo creek	J. Langenbach	Dorchester	Grist	15	15	Sec. 24, Waterloo Tp.
Quandahl	Bear creek	Peter Quandahl	Quandahl	Grist and saw	15	15	Sec. 30, Waterloo Tp.

Mr. Ratcliffe adds that, on account of the decadence of milling interests and the change from wheat raising to dairying, many water powers that were formerly in use have been abandoned. In addition to the foregoing list there are at least twenty-four abandoned mill powers that might be enumerated. With the coming demand for energy for other purposes than

Figure 12. Cascades in gorge of Trenton limestone at Pinney's Spring.

milling, all the old mill properties will once more become valuable, and all the possible properties of the kind that have never been improved will be harnessed to useful work, and made to furnish employment to labor, while supplying comforts and conveniences to homes of intelligence and refinement.

GEOLOGICAL MAP.

The geological map accompanying this report shows approximately the distribution of the various formations of indurated rocks in Allamakee county. A separate map would be necessary to show the superficial deposits. Of the several indurated beds there are many narrow tongues and outlying areas that could not well be represented without confusion on a map of this scale. Only one lead mine is represented, for though lead has been mined at many points within the county, the amounts

taken out have been too small to justify the recognition of mines except at the one point indicated. Clays are everywhere abundant, but only at Waukon have sustained efforts been made to utilize them. Stone quarries have been opened at hundreds of points within the county and have been worked to a greater or less extent. In every township, in almost every section, there are many rock exposures capable of affording useful material for many purposes. It is obviously impossible to indicate all of these points without covering the map with quarry symbols. It is to be understood, therefore, that the points symbolized as stone quarries are only a few of the more important localities where stone has been taken out. Lime has been made in small quantities in almost every neighborhood, but the lime kilns indicated at Waterville are the only ones that have been persistently operated on a commercial scale.

ACKNOWLEDGMENTS.

The Survey is under obligation to many citizens of the county, indeed to all with whom its representatives came in contact, for intelligent interest and substantial assistance. Especial acknowledgments are due to Mr. Ellison Orr, of Postville; Mr. Charles Barnard, Judge M. B. Hendrick, Mr. A. M. May, Engineer J. G. Ratcliffe, and Mr. Langford May, of Waukon, and to Captain J. M. Turner, and Hon. James H. Trewin, of Lansing.

These men all possessed knowledge of local phenomena of geological interest, and all freely gave their time in contributing important facts, or in conducting the representative of the Survey from point to point, with the result that the data he might require for the solution of the geological problems which this most interesting division of the state presents were collected and noted in much less time than would otherwise have been possible.

Mr. J. G. Ratcliffe collected and mapped the topographic data without which the mapping of the geological formations would have been practically impossible; and the Survey is indebted to Prof. T. H. Macbride for the interesting subjoined paper on the forests of Allamakee county.

FOREST TREES OF ALLAMAKEE COUNTY, IOWA.

BY PROF. T. H. MACBRIDE.

The forests of Iowa have never been adequately studied. Indeed, so far as known, no systematic attempts have ever been made to render proper account of this most important section of our native flora. We have been so engrossed by the unmatched wealth and fertility of our prairies that our woodlands have been largely ignored, or thought of only as obstacles to be gotten rid of as rapidly as possible. This has ever been the American view of the subject. The older nations of the world, struggling by great expenditure of labor and money to maintain forest conditions in their own crowded communities, look aghast at the wasteful recklessness prevalent in the United States, where by nature we possess, but thoughtlessly turn over to destruction, that which they toil so earnestly to secure. Fortunately for us our people are at last awaking to some appreciation of the situation. The increasing rigor of our inland climate, increasing intensity of cold in winter and heat and drought in summer, with ever swifter and more sudden alterations of extremes of heat and cold, the increased erosion of our lands, accompanied by increased irregularity in the volume of all our streams, the alternate flooding, and the choking of even great rivers like the Des Moines and the Mississippi—all these facts are at last beginning to attract the attention of people generally, and to enable them to see that by the wide occupation of our country we have in some serious way disturbed the orderly operations of Nature. We have accelerated the operation of forces which bring to us, as civilized men, evil and only evil, and that continually. Among the causes which are bringing about these deplorable results are some which are incident to the very fact of the presence of civilized man. Civilized men are agriculturists. They continually loosen the surface of the ground for the cultivation of crops and so incidentally contribute very largely to the erosion which chokes our streams. A more careful husbandry will eventually, in large measure, remedy this by such use of the land as will prevent, to a very large extent, the removal of the soil.

Individual self-interest will look out for this. But there are other factors in our problem much more far-reaching and difficult to manage. Of these, perhaps, the principal is that which pertains to the question of forestry. It is a fact long undisputed that the presence of a certain amount of forest is absolutely essential in those lands which are to remain the habitation of enlightened humanity. This does not mean that there shall everywhere be found trees planted about the homes of men. What is here intended is that in all parts of the country there shall be found regions where the land is given up to trees, where true forest conditions prevail. This was the condition of affairs when civilization first came into the Mississippi valley. In Iowa, for instance, every stream was bordered by natural woods which extended more or less widely over river bottoms and fertile flats, filled up as well every narrow ravine and covered every precipitous hillside, while Wisconsin and Minnesota, as we all know, were largely clothed with dense forests of coniferous trees. Now it is undisputed by all men competent to judge, that such forests greatly modify climate. They form efficient obstacles in the pathway of sweeping winds; also, a yet more important particular, they constitute vast reservoirs of moisture, prevent its rapid dissipation, render more humid the atmosphere and more regular the rainfall over vast areas in regions where such forests are found. Now what is the present situation? We have ruthlessly destroyed the forests of the two great states mentioned; by our methods have almost utterly obliterated the natural woods, leaving a desert in their place. The results are now felt in the whole Mississippi valley. The year 1894 shows a drought such as was never heard of before. In Iowa, too, the same destructive agencies are at work. In the greater part of the state lumber trees, old trees, have long since been nearly all cut away, while the "second growth," which might be efficient, which might stand in place and maintain for us the little forest-conditions that the state at first enjoyed, is rapidly disappearing before the axe of those whose effort is to convert even our steep clay hillsides to purposes of pasture and tillage. We have had so little woodland from the outset that the effect of our clearing is sure to be the more

speedily felt. This effect will be manifest in Iowa, rather in the consequent irregular flow of our streams. We shall have, instead of clear rivers and springs and creeks, such as the older residents of the state well remember, flowing the year through, nothing but waterways, now flooded by destructive muddy torrents confined by no legitimate channel, now dry runs, now wide reaches of sand; with dearth of water in all fields and pastures.

In view of such facts and conditions what shall be done? We cannot do anything for Minnesota and Wisconsin. Those great commonwealths must act for themselves, as they will presently, the more energetically as the interests involved are vaster. We, however, residents of fruitful Iowa, must do something. We must spare the forests we have. Every man owning forest lands must be taught to prize his possession. He has, by Nature's effort, that which money cannot restore. Not that he shall cut no trees, but simply that he shall not extirpate the woods. He shall preserve the forest conditions and allow the forest, as it will, to continually renew itself. Especially must this be done along steep hill sides and along all the water courses of the state. We are in danger of seeing in Iowa the conditions which obtain in western Nebraska and Kansas. Our only hope lies in the wisdom of our people. The state, therefore, cannot too soon begin to spread information on this subject. It is even now too late to know the whole truth. Our study of Iowa forestry must depend upon knowledge derived from examination of a remnant. A thorough report on the present conditions of the state in this regard is most urgently needed. Such report should be accessible to every citizen, to the end that universal information should create a popular sentiment favorable to forest preservation.

The present paper aims simply to present a few facts observed in a recent somewhat hasty survey of the hills of Allamakee county. This region of the state offers many geological peculiarities. These are reviewed more or less exhaustively elsewhere in this report. To trace the relationship between these topographical conditions and the spread of the native forest would be an interesting endeavor for which we

have at present hardly sufficient data. Even under existing conditions we may, however, determine some facts pretty clearly.

Except in special localities the primeval forest in Allamakee county, as elsewhere in Iowa, was, when first seen by white men, not dense as it has since appeared. I have been informed by men who traversed the woods more than sixty years ago, that at that time one could drive a wagon anywhere through the Iowa forest. We may well believe this if we observe simply the old trees, where these yet remain, and remember that all the crowded smaller trees have come up within the last thirty or forty years. Fire is the great check to the extension of the forest, and prior to the occupancy of Iowa by civilized men fires were sufficient to so far retard forest growth that only a few trees found place where now stands the impenetrable so-called "second growth." In that early day a large portion of Allamakee county was covered with such forests, especially the eastern half of the county. Not only the river valleys and the hillsides sloping to them were wooded, but even the flat hilltops, now cultivated, were covered by scattering trees. At present the old trees which constituted the entire forest primeval are mostly gone. Here and there, for one cause or another, a few remain, but throughout the county the best and largest have, even within recent years, found their way to the saw mill.

It is claimed by some people that the second growth occupies really more territory than that occupied by the original timber; that it has actually invaded the prairie. This might have been possible if the prairies had remained long untilled subsequent to the suppression of the fires; but inasmuch as the suppression was that the prairie might be occupied by agriculture, it seems probable that the second growth hardly marks the extent of the original wooded district, much less overreaches it. The number of individual trees may possibly be greater now than before, because the smaller trees are much more closely crowded.

Prairie fires have been mentioned as the probable check to the westward extension of the woodlands of Iowa. This is only one of the factors in the problem and this itself is conditioned upon another, viz: the amount of moisture prevalent in the

region, that is the amount of precipitation of rain or snow. If the rainfall of spring is sufficient to make the ground quite wet until the season of spring prairie fires has passed, the seedlings of the forest have a chance to start and grow for some months before they are in peril of fire in the fall again. If in this latter season there is sufficient rainfall, and if during the winter the country is buried in snow, the danger from fire is so far minimized, and the young trees have a chance to attain considerable size before the unequal seasons bring about conditions that shall subject the saplings to the test of fire. It follows from this that, other things being equal, those particular localities will be more favorable to the occupancy by trees where the amount of moisture is greater, and especially where it is more continuous from month to month throughout the year. Now it is a matter of common observation that in a hilly country, in the Mississippi valley at least, the south and west hillsides are dryer than those sloping to the north and east. This, for two reasons. In the first place the afternoon sun dries the first named hill-

Figure 13. Bluffs showing characteristic distribution of timber.

sides more competely. North slopes in our latitudes are for only a few months exposed to the sun at all; eastern slopes have the advantage of the dewfall and the coolness of the night before meeting the heat of the morning sun; while the south slopes lie all day long beneath the hottest rays, and the west

endures the heat of the afternoon. In the second place, our prevailing winds being from the west, the greatest amount of snow is always lodged on eastern or southeastern slopes. Of all these conclusions Allamakee county shows us a remarkable confirmatory illustration. The observer has but to drive across the county anywhere to discover that the southwestern sides of all the rounded knolls and hills are bare; always have been. This is plainly shown in figure 13 from a photograph taken near the center of section 16 in Union City township. This circumstance is not due to difference in soil, level, pitch or anything of that sort, for these factors around the hill are just the same. The difference comes wholly from unequal amount of moisture received and retained.

A casual examination of the case in Allamakee county illustrates still another fact in reference to Iowa's forest trees, that is that some are much better adapted than others to unequal conditions such as just described.

The bur oak, for instance, comes nearest to being able to occupy the unfavorable sides of an Iowa hill. Let anyone take the road leading south from Silver creek in the direction of Waukon (Tp. 98 N., R. V W., secs. 3 and 4). The road for some distance follows a ridge of Trenton limestone. Here the west side of the road is occupied by bur oaks almost exclusively. Hickories, black oaks, scarlet oaks, etc., abundant to the east, hardly pass the middle of the ridge. This fact is so patent that it is sure to attract the attention of anyone merely driving along the highway. This hardiness of the bur oak is in accordance with what may be observed elsewhere in regard to its general distribution. The species is found entirely across the state and as far west at least as the Black Hills of South Dakota. In many cases it forms a scrubby grove upon the prairie, the only species of arboreous plant for miles and miles.

The following is a list of the larger trees observed growing native in Allamakee county:

Tilia americana L., Basswood. Common.

Acer saccharum Marshall, Sugar Maple. Common, especially along streams.

Acer saccharinum L., Soft Maple. Common. Commonly planted everywhere.

Acer spicatum Law., Mountain Maple. Rare, along the bluffs of the Mississippi.

Negundo negundo (L.) Sudworth, Box Elder. Common everywhere and commonly planted.

Rhus typhina L., Staghorn Sumach. Common in the eastern part of the county, especially along the bluffs overlooking the Mississippi river, where trees eight inches in diameter and forty feet in height may be seen.

Robinia pseudacacia L., Common Locust, Black Locust. Common. Subject to the destructive attack of a species of beetle which a few years since threatened the existence of the species in this part of the world, at least rendered the tree useless for economic purposes. Within the last ten years, however, the beetle seems to have met with some check which greatly diminishes its power for evil, and the Locust is rising to its former importance as a timber tree.

Gymnocladus dioicus (L.) Koch. The Kentucky Coffee-tree. Not common.

Gleditschia triacanthos L., Honey Locust. Not common, but seen in a few places near the Yellow river.

Prunus americana Marshall, Wild Plum. Everywhere common.

Prunus serotina Ehrh. Wild Cherry, Wild Black Cherry. Not uncommon.

Cratægus coccinea L., Common Hawthorn. Not rare.

Cratægus tomentosa L., Scarlet Thorn. Common.

Amelanchier canadensis Torr. and Gray. Service Berry, Shadbush. Not rare along rocky banks.

Fraxinus americana L., White Ash. Common.

Fraxinus expansa Willd., Green Ash. Common.

Ulmus pubescens Walt., Slippery Elm. Common.

Ulmus americana L., American Elm, White Elm. Common.

Ulmus racemosa Thomas, Cork or Rock Elm. Beautiful specimens of this tree occur in all the valleys visited. The species is very distinct, recognizable from afar by anyone who

has once compared it with either of the other two common species.

Celtis occidentalis L., Hackberry. Not rare.

Morus rubra L., Mulberry. One tree only noticed near the mouth of Yellow river.

Platanus occidentalis L. Common along streams, especially near the Mississippi river.

Juglans cinerea L., Butternut, White Walnut. Common.

Juglans nigra L., Black Walnut. Common. A few large trees still occur here and there, and no grove of "second growth" on rich land seems to lack its quota of this most valuable species.

Hicoria ovata (Mill.) Britt, Shell-bark Hickory. Common.

Hicoria glabra (Mill.) Britt, Pig Nut, Brown Hickory. Common.

Betula papyrifera Marshall, Paper Birch, Canoe Birch, White Birch. Not uncommon. Certainly confined to the northeastern corner of the State.

Betula nigra L., River Birch, Red Birch. Common along the Mississippi river.

Alnus incana Willd., Speckled Alder, Hoary Alder. Common along Yellow river.

Ostrya virginica Willd., Ironwood, Hop Horn-bean, Leverwood. Common.

Carpinus caroliniana Walter, Blue Beech, Water-Beech, Ironwood. Common on rocky banks along streams.

Quercus alba L., White Oak. Common.

Quercus macrocarpa Michx., Bur-Oak. Common.

Quercus muhlenbergii Engelm., Chestnut Oak. Common or, at least, not rare.

Quercus rubra L., Red Oak. Not rare.

Quercus coccinea Wang., Scarlet Oak. Not rare.

Salix nigra Marsh., Black Willow. Common in various parts of the county.

Populus tremuloides Michx., American Aspen, Quaking Asp. Common.

Populus grandidentata Michx., Quaking Asp, Poplar. Common.

Populus monlifera Ash., Cottonwood, Necklace-poplar. Common. Commonly planted in prairie parts of the county.

Pinus strobus L., White Pine. Not uncommon on the higher ridges.

Abies balsamea Miller, Balsam. Not rare. A fine grove on the hill above Yellow river, near Myron.

Juniperus virginiana L., Red Cedar. Not rare on rocky ledges.

Map 1

GEOLOGY OF LINN COUNTY.

BY

WILLIAM HARMON NORTON.

GEOLOGY OF LINN COUNTY.

BY WILLIAM H. NORTON.

CONTENTS.

INTRODUCTION.

SITUATION AND AREA.

Linn county is situated in the east central part of the state and lies athwart the valleys of the Buffalo, Wapsipinicon and Cedar rivers, extending from the Buffalo-Maquoketa divide on the northeast to and beyond the Cedar-Iowa divide on the southwest. It is rectangular in shape and contains seven hundred and twenty square miles.

PHYSIOGRAPHY.

DRAINAGE.

The three large streams just mentioned trench the county from northwest to southeast to a depth of from two to three hundred feet below the summits of their interplains. The gradient thus afforded to their affluents has been sufficient to enable them to push their subordinate waterways so completely into the inter-stream areas that marshes are not found of any extent. No lakes exist except here and there a moat on the flood plains of the rivers, and a few ponds in depressions in the drift. The drainage system is therefore well advanced beyond the earliest stages in its development.

By far the larger part of the county lies in the catchment basin of the Cedar river. To the south the Cedar valley is narrow, the divide being reached in from two to eight miles from the stream, the only considerable affluent being Prairie creek, whose general direction is eastward. To the north the Cedar valley extends to within from one to three miles of the Wapsipinicon river, and is drained by several large creeks flowing nearly due south in parallel courses. The largest, Indian creek, is about twenty miles in length.

TOPOGRAPHY.

Linn county is included in the area covered by the hypsometric atlas sheets of the United States Geological Survey, so that the relief is known with reasonable accuracy. The relief of the county may be described as consisting of two paha belts of hilly country, parallel and adjacent to the largest rivers, with

an intervening drift plain. The general elevation of the central plain is between 800 and 900 feet above tide. Below this level the rivers have cut to as low as 685 feet above tide, while above it the paha ridges, which are described in detail in subsequent pages, rise to a maximum measured height of 1,240 feet above tide. The presence of these ridges near the rivers, in combination with the more active erosion at these points, gives a much more rugged topography along the streams and sharply contrasts the stream and plain areas.

The following table shows the elevation above sea level of the principal towns and villages in the county.

Table of Elevations.

LOCALITY.	AUTHORITY.	ELEVATION.
Bertram.	C. & N.-W. Ry.	720
Cedar Rapids.	City datum.	708
Center Point	U. S. G. S.	820
Coggan.	U. S. G. S.	860
Ely.	B., C. R. & N. Ry.	741
Fairfax.	C. & N.-W. Ry.	773
Linn Junction.	U. S. G. S.	756
Lisbon.	C. & N.-W. Ry.	877
Marion.	U. S. G. S.	840
Mount Vernon.	C. & N.-W. Ry.	847
Otis.	U. S. G. S.	740
Palo.	U. S. G. S.	751
Paralta.	U. S. G. S.	840
Springville.	U. S. G. S.	840
Toddville.	B., C. R. & N. Ry.	780
Viola.	U. S. G. S.	900
Waubeek.	U. S. G. S.	840

STRATIGRAPHY.

General Relations of Strata.

The indurated rocks of Linn county belong to three great systems: Silurian, Devonian and Carboniferous. It is possible that Cretaceous strata may hereafter be found to occur in the form of small remnants.

The Silurian rocks found within the county belong to the upper portion, and occur in six minor divisions. They are succeeded by the Devonian, which has not yet been completely classified for Iowa. In Linn county there are a number of well marked stages which, for the present, are given local names.

The Carboniferous occurs only as outliers. Over the indurated rocks is spread a mantle of drift, or unconsolidated deposits of Pleistocene age, which in this county present particularly interesting features.

The following table shows the formations exposed in the county.

Classification of Formations.

GROUP.	SYSTEM.	SERIES.	STAGE.	SUB-STAGE.
Cenozoic.	Pleistocene.			Alluvium. Loess. Pre-Loess Sands. Second Till. First Till. Residuary Clays.
Mesozoic.	Cretaceous.			
Paleozoic.	Carboniferous.	Upper.	Des Moines.	
	Devonian.		Cedar Valley.	
			Wapsipinicon.	Upper Davenport. Lower Davenport. Kenwood. Otis.
	Silurian.	Upper.		Coggan. Bertram.
			Anamosa.*	
				Le Claire.
			Delaware.	Coralline. (?) Pentamerus.

The general dip of the rocks of Linn county, like that of the geological formations of the state, is toward the southwest.

* Substituted for Mount Vernon as used in the text at the suggestion of Dr. Calvin.

The lowest strata, therefore, in the geological column of the county are found in the northeast townships.

Geological Formations.

SILURIAN.

PENTAMERUS OBLONGUS BEDS.

These beds of the Upper Silurian enter Boulder and Jackson townships from Jones and Delaware counties, extending as the country rock as far west as Nugent's quarry, one mile east of Coggan. From this point a more rapid dip carries them at Coggan below the bed of Buffalo creek. The descent of the creek displays them again five miles southeast of Coggan at Hill's mills (Tp. 86 N., R. V W., sec. 29, Se. qr., Nw. ¼). Here a section of twenty-four feet of strata is given above water in the Buffalo, presenting the characteristic features of the terrain. The rock is throughout a buff, cherty dolomite, rough bedded, with courses ranging in thickness from two feet four inches at the base to six inches above, parallel, constant and to the eye horizontal. *Pentamerus oblongus* Sowerby, abounds throughout in casts of limestone and chert.

Nugent's quarry has some nine feet of the same rock, but in thinner layers, also abounding in casts of the same fossil. The upper foot or so is of finer grain and the Pentamerus casts are in calcite instead of chert and limestone as beneath. This merges into a foot of thin buff calcareous plates which may be transition beds of another terrain.

CORALLINE BEDS.

Beds of the Upper Silurian higher than the life zone of *Pentamerus oblongus* appear one and one-quarter miles east of Central City (Tp. 85 N., R. VI W., sec. 1, Sw. qr., Nw. ¼). The limestone here exposed at the foot of a hill is four feet thick with an interesting contact, to be described hereafter, with the Coggan beds above. It is a hard, bluish gray dolomite, containing numerous limestone casts of corals, but destitute of *P. oblongus.* A fragment was noticed of a pygidium of Bronteus, probably *B. laphami*, though apparently somewhat shorter. In

Central City, at water level just above the dam, a massive dolomite is exposed from which also *P. oblongus* is absent. This sub-stage will probably be recognized in the detailed study of the Upper Silurian of other counties and may then receive a more appropriate designation.

LE CLAIRE BEDS.

This terrain occupies a narrow strip along the eastern boundary of the county from Viola to the Cedar river, reaching here its ultimate northwestern exposure in the state. At the lime quarries at Viola, belonging to S. H. Gulick, the hard, vesicular, sub-crystalline dolomite repeats not only the physical characters of the dolomite at Le Claire, but is also affected by the same anomalous dip which obtains at that typical locality. At the south quarry, the heavily bedded layers at the south end dip 19° north. The dip lessens toward the north end of the quarry, where it is 8°, east 23° north.

At the north quarry, one-half mile distant, the lower layers dip 3°, west 16° south. They are heavily bedded, from four to six feet thick, and are succeeded by thinner layers, which are one foot thick at the top of the quarry. At the south end of the quarry the courses are all parallel and dip about the same. In the center, however, the lower and middle layers merge into an obscurely stratified mass, above the nearly level surface of which the upper layers, eight feet in thickness, bend down with a northeasterly dip of about 10°.

The Le Claire beds reappear at Mount Vernon and Lisbon, and on the Cedar they outcrop at intervals from the south county line to Ivanhoe bridge. Above this point they front the river in vertical cliffs, locally called the Palisades, nearly to Cedar Springs hotel southeast of Bertram. The outcrops gradually increase in height from the county line until about a quarter of a mile below the hotel where the maximum height of eighty-nine feet above water is reached. From this point (Tp. 82 N., R. VI W., sec. 14, Nw. qr., Nw. ¼) the Le Claire rapidly sinks and, in less than half a mile, disappears beneath the flood plain of the river. From the summit to the base these cliffs are, for the most part, formed of one massive layer undivided by bedding

planes and unbroken by lithological alternations. While the rock is broadly homogeneous, there are slight variations in hardness and texture, producing cavernous recesses in its walls and the irregular relief characteristic of long-weathered surfaces of this dolomite. Near water level rude and inconstant courses, approximately horizontal, appear in places. Below Ivanhoe bridge bedding becomes more distinct and extensive in the rock, the dip being gentle and somewhat various.

Where quarried for lime the quarry face presents a conglomeratic aspect, due, perhaps, in part to variation in the resistance to weathering in different portions of the rock. Thus large masses are blasted out, the centers of which are hard and bluish gray, but having surfaces that are buff and somewhat carious. Much of the rock is minutely vesicular from the removal of small fragments of fossils and has therefore a trachytic harshness to the touch. When these vesicles are of some size they are stained with ferric oxide. Silica in any form is absent. In places fossils are so numerous as to affect distinctly the texture of the rock. Bands are seen several feet in thickness, made up wholly of the interstitial filling between moulds of Rhynchonellas, or of a small spire-bearing shell, or of casts of large crinoid stems.

At the lower lime quarry, now abandoned, there are numerous nests of the saucer-like cephalic and tail shields of *Illænus ioxus.*

Though the fauna of this limestone in Linn county differs from that of the typical Le Claire in Scott county, the difference is probably due to geographical rather than secular causes.

MOUNT VERNON BEDS.

The Le Claire limestone, as defined by Hall, included only the hard, brittle, sub-crystalline "limerock" at Le Claire and Port Byron, whose appearance, except in bedding, is substantially the same as that of the dolomite just described.

At Le Claire this is succeeded by a soft, even bedded, granular, but not crystalline, buff or drab limestone, stated by Hall to rest in synclinal axes of the Le Claire, and referred by him to the Onondaga Salt group. This upper limestone has a

wide distribution over the Upper Silurian area in Iowa. The question of its relation to the Le Claire is an interesting one, complete data for the solution of which are perhaps not yet at hand. In the later geological literature of the state the relation has been supposed to be sufficiently close to warrant the extension of the term Le Claire to cover these beds also. Though the limestones in question may be practically contemporaneous, still their lithological differences, and to some extent their biotic differences, are marked and constant. Even if these are due only to varying conditions of deposition, accuracy and convenience in description will be subserved by the use of a local term, waiving for the present the question of the relationship of these beds to the geological series in other states. For this reason the upper limestones are here referred to as the Mount Vernon beds, since at that place they present their distinguishing lithological features and contain also a rich fauna, the beds elsewhere, with perhaps a few exceptions, being unfossiliferous. This limestone is sufficiently soft to work with ease, but hardens on exposure. Bedding planes are constant, even, parallel, and usually horizontal or with gentle synclinal or anticlinal dips. The courses are often heavily bedded, but are finely laminated, disintegrating in quarry strippings into thin, soft spalls. The stone is distantly jointed. It is granular, varying from an almost lithographic fineness to a coarser rock, sometimes called "sandstone" by workmen, although silicious sand is quite absent. The fracture is even, following the impact of the hammer in any direction. On fresh surfaces the luster is dull, relieved by scattered minute, sparkling crystalline facets. Sometimes the rock is minutely vesicular, or contains larger cavities filled or lined with quartz or calcite or with both. In color it varys from a warm gray or light cream tint to pale or darker buff, sometimes reddened by ferric oxide. chert nodules are common and thin layers of black flint rarely occur.

The most southern exposures noted in Linn county lie about three-quarters of a mile apart on either side of an amphitheater of hills which opens broadly upon the right bank of Cedar river at Ivanhoe bridge. On each side of this ancient flood plain the

Le Claire rises in cliffs about fifty feet high, the Mount Vernon beds abutting upon it or graduating into it laterally, the actual contacts not being visible.

The southeast outcrop (Tp. 82 N., R. V W., sec. 32, Nw. qr., Nw. ¼) is as follows:

		FEET.
3.	Loess and humus, forming summit of ancient terrace	4
2.	Geest, with drift pebbles	½
1.	Limestone, soft; upper layers thin and rotten spalls, layers quarried four to nine inches thick, rock compact, but some layers highly vesicular with dusty cavities up to 3 inches in diameter (Mt. Vernon beds)	8

In the northwestern quarry, Anton Novak's, the rock is distinctly of the Mount Vernon type, though vesicular. It dips about two degrees to the northwest. The quarry face is about twenty-four feet high and its base is below high water in the river.

The rock of these two quarries once formed a continuous stratum occupying a depression in the Le Claire at least fifty feet deep, and the present topography seems due in part to the difference in obduracy of the two beds.

The relation of the Mount Vernon beds to the LeClaire may be studied also at the Upper Palisades. Not one-half a mile to the northwest of the highest cliffs of the Le Claire (89 feet high), the Mount Vernon is found in a slight excavation at Cedar Springs hotel on a level with the flood-plain of the river. In places along the descending cliffs of the Upper Palisades, the Le Claire shows obscure stratification lines dipping to the northwest as much as thirty degrees. Along the summit of the rapidly sinking ledge the massive, vesicular limerock is seen to graduate laterally and vertically by intercalation, into even layers of crystalline dolomite from three to eight inches thick and finely laminated, the laminæ being defined by lines of discontinuous cavities about 1 mm. in diameter. These layers differ from the Mount Vernon beds in their crystalline texture. On the flat face of one layer a common fossil of the Mount Vernon and Stone City quarries was noted, the upper surface being covered with convex, rod-like bodies, from 1 mm. to 2 mm. thick and from 10 mm. to

nearly 20 mm. long, without joints, slightly flexuous or vermicular, the same individual varying slightly in thickness and often tapering at the ends. The attitude of these thin upper layers, apparently transition layers to the Mount Vernon, is significant. They dip strongly to the northwest—one dip of forty-one degrees was measured—but curve to nearly horizontal within a few yards, forming a quadrant whose convexity is southeastward. Where especially noted they are fifteen feet thick, including three feet of interbedded "limerock."

The heavy northwest dip of the Le Claire at this point and its passage into the softer Mount Vernon beds, together explain in part the topography of the region, the sudden change from the gorge of the Palisades to the wide alluvial plain extending on the left bank to Bertram.

At Mount Vernon a similar juxtaposition of the Mount Vernon and the Le Claire beds may be observed. The quarries of the former, belonging to Messrs. Platner, Gregg and Kirby lie some fifty feet higher than the summit of the Le Claire at the Palisades. At about forty rods distant the Le Claire emerges at Robinson's lime quarry in a knob of conglomeratic limerock of which about twelve feet is exposed. On the east side it merges into regularly bedded sub-crystalline limerock, the layers being from four inches to one foot thick and nearly horizontal. On the opposite side it is flanked by the Mount Vernon limestone, which has at first considerable outward dip, but in a few feet becomes horizontal. This part of the quarry has not been worked for years and the actual contact cannot be seen. Borings made in the Platner quarry show that the Mount Vernon stone extends at least sixty feet below the top of Le Claire at Robinson's quarry so few rods away.

A slight deformation causes the Mount Vernon beds to reappear six and three-quarter miles northwest of Mount Vernon in a section described on succeeding pages.

On the Wapsipinicon river these beds extend from Stone City to Waubeek, affording some of the largest and best quarries of building stone in the State.

The following theories have been proposed to account for the deposition of the Mount Vernon beds in these deep hollows of the Le Claire:

(1) The theory of unconformity with a long time interval, during which the troughs in the Le Claire were eroded. This is negatived by the close paleontological relation of the two beds, by the lithological gradation between them and by the occurrence of crystalline "limerock," in places in several counties, upon the granular limestone of the Mount Vernon beds.

(2) By unconformity, the troughs in the Le Claire being synclinal folds. This requires no considerable time-interval, though Hall, who proposed it, allotted the two beds in question to different geological epochs. Some of the objections to the first hypothesis apply here also. Hall has since suggested that the dip of the strata at the Le Claire with which he defined the apparent synclines may be due to false bedding.* Certainly any measurements of the thickness of the strata at Le Claire based on the assumption of true dip give results grossly in excess of what can be conceded. For a distance of about 3,300 feet below the village there is a continuous northern dip which must average at least ten degrees. This would give a thickness to the Le Claire of 570 feet. Yet at Davenport, twelve miles distant, the total Upper Silurian, as measured in the artesian wells of the city, cannot be over 320 feet thick.

(3) By simultaneous deposition of the two limestones under different conditions, the "limerock" representing the irregular aggregations of coral reefs, and the granular limestone, off-shore deposits of calcareous sediments derived largely from the reefs. This theory has been skillfully worked out in detail by Chamberlin in the Wisconsin field, where a like association of similar limestones occurs,† and seems best to explain all the phenomena of the Le Claire observed in Linn county. No conclusive proof has, however, yet been fonnd that the Mount Vernon beds were formed simultaneously with the reef rock. Their great thickness, reaching over fifty feet at Stone City and seventy feet at Mount Vernon, their wide distribution over the central counties

*Twentieth Annual Report Regents N. Y., p. 307.

†Geology of Wisconsin, vol. II, pp. 330-371. 1877.

of eastern Iowa, the appearance in them of post-Niagara species, absent in the Le Claire, indicate that they represent a somewhat later stage of Silurian sedimentation. The gradations observed in this county between the two beds are not more close than obtain between beds whose succession in time is unquestioned.

The Mount Vernon beds were evidently laid down in shallow water. At Waubeek beautiful ripple marks attest the nearness of the soft calcareous silt to the surface of the sea. In the Mount Vernon quarries calcareous "mud-cracks" indicate a still higher position.

BERTRAM BEDS.

In the southeastern and central part of the county the limestones just described are succeeded by a well defined series of beds exposed along Big creek and its tributaries from Springville and Paralta to Bertram. Along this line, nearly ten miles long, abounding in natural sections, the rock is practically the same. It is a magnesian limestone, slow to effervesce in dilute hydrochloric acid, though ultimately dissolving completely, and yielding considerable magnesian precipitate. It is hard and brittle, breaking with an uneven or sub-conchoidal fracture. In color it varies from a light to a medium drab on fresh surfaces but weathers to light gray or white. In structure it is compact, non-crystalline, non-granular. It exhibits occasional brecciation or heterogeneity of structure, owing apparently chiefly to conditions of deposition, since the regularity of the courses is seldom interrupted. Where this brecciation occurs the fragments are always small, usually minute, and like the matrix.

Weathered surfaces are sometimes smooth, sometimes pitted and rough with fantastic projections similar to those on weathered surfaces of the Niagara, but the relief is on a much smaller scale. The upper surfaces of detached blocks are usually crackled with a network of incised lines, the meshes being often rhombic and varying from a fraction of an inch to a few inches in width. Connected with this is the tendency of the rock to weather into small rhombic chipstone. At the Chicago, Milwaukee & Saint Paul railway bridge over Big

creek southwest of Paralta, the upper five feet of this rock, though remaining in place, is divided into such prismatic blocks by two sets of fracture planes. A freshly fractured horizontal surface often shows thin veins of calcite, and where the structure is more heterogeneous, calcite is interstitial. In the Bertram beds are found the first evidences of those stresses whose maxima are registered in the Fayette breccia.

Notwithstanding the facts we have mentioned, the rock is commonly heavily bedded. Numerous sections along Big creek record layers two, three and even five feet thick. In one section (Tp. 83 N., R. VI W., sec. 26, Nw. qr.) two layers at the top, each five feet thick, and a basal layer eight feet thick, inclose twenty-four feet of the same drab limestone standing in a nearly vertical ledge, though more thinly bedded and tending to weather into chipstone. An adjacent hillside about fifty feet high is strewn from the summit three-fourths the way to the base with immense blocks of this stone, some being fifteen feet long.

On the whole, courses are quite constant and usually to the eye nearly horizontal, though roughly surfaced. The rock is often finely laminated, the harder laminæ standing in relief on weathered surfaces. These lines are not even and parallel as in the Mount Vernon stone, but slightly flexous. Sometimes a harder lamina is seen to be a true horizontal vein. Close, thin, discontinuous, nearly parallel cracks, undulating, but approximately horizontal, are seen filled with calcite. Near the surface the calcite is dissolved, leaving the rock apparently laminated, the divisions being marked by reddish stained cavities. No fossils have been found except one or two imperfect moulds of an exceedingly minute brachiopod. The position of the Bertram beds relative to the Mount Vernon beds is clearly seen in a low anticlinal, cut across by the valley of Big creek. This fold is the continuation of the deformation to which the presence of the Upper Silurian in the east central and southern parts of the county is due. The crest extends northwestward from Mount Vernon. The following section is taken at the summit of the arch (Tp. 83 N., R. V W., sec. 7, Sw. qr., Ne. ¼).

		FEET.
5.	Slope, covered with imbedded fragments and blocks of Bertram limestone; near the base a block or ledge six feet thick, actual contact with No. 4 not observed, though but a foot or so apart	28
4.	Dolomite or magnesian limestone; hard, compact, saccharoidal; light gray in color, weathering yellow; in vertical cliffs, with courses more or less obscure, dividing and again reuniting, resembling rough masonry; layers beneath becoming thinner and more distinct	19½
3.	Dolomite or magnesian limestone; dark grey, crystalline, similar to No. 4, but evenly and distinctly stratified in layers one-half inch to three inches thick; weathering into chipstone with quadrangular faces.	3
2.	Not exposed	1½
1.	Limestone; fine granular, buff; in a vertical ledge, splitting readily into thin layers with abundant casts of Leperditia (Mt. Vernon beds), to water in creek	12

Three-fourths of a mile to the southwest, at the ford of Big creek (Tp. 83 N., R. VI W., sec. 13, Ne. qr., Ne. ¼), No. 4 of the above section has declined to twenty feet above the water in the creek and is overlain by thirty-four feet of the Bertram limestone, but two feet separating the distinct outcrop of the two beds. Nearly two miles further to the south, the same dolomite reappears at water's edge at the bridge over Big creek on the Marion road (Tp. 83 N., R. VI W., sec. 23, Nw. qr., Se. ¼). To the north of the summit of the arch in the section given, the dolomite dips more rapidly, passing out of sight within three-quarters of a mile.

The Bertram beds are found as far east as school house No. 7 (Tp. 83 N., R. VI W., sec. 25, Se. qr.), on Carraway creek, and on the Chicago and Northwestern railway one mile east of Bertram. They have been traced as far north as one mile northeast of Springville (Tp. 84 N., R. V W., sec. 22, Sw. qr., Sw. ¼). There is at this point a typical outcrop some eleven feet above the track of the Chicago, Milwaukee and Saint Paul railway at a road crossing. A gully discloses above the Bertram beds four feet of a soft, earthy, buff, magnesian limestone, with many cavities and numerous moulds and casts of a small

smooth surfaced Spirifer which does not seem to agree entirely with any Upper Silurian species.

The same magnesian limestone, with similar cavities or casts, is found overlying the Bertram beds on Carraway creek, on the Chicago and Northwestern railway one mile east of Bertram, and on Big creek (Tp. 83 N., R. V W., sec. 6, Nw. qr., Sw. ¼), but at none of these places is it exposed as a continuous layer as at Springville.

COGGAN BEDS.

The Bertram beds dip toward the west, since at the first outcrops west of Big creek, four and one-half miles west of Bertram, they have passed out of sight, and the soft, buff, magnesian fossiliferous limestone just mentioned forms the base of the sections. This limestone, which may be called the Coggan beds, as it is typically developed at that place, is succeeded by non-magnesian limestones, the Otis beds. Above these lie the Kenwood shales, which in turn are subjacent to the lower limestones involved in the brecciated zone which has been called by McGee the Fayette breccia.

SECTIONS OF THE COGGAN, OTIS AND KENWOOD BEDS.

The following detailed sections show representative facies of all these beds. Three-fourths of a mile east of Otis, quarries on the Chicago and Northwestern railway disclose the following succession of layers:

		FEET.	INCHES.
18.	Limestone, yellowish or grey, highly argillaceous, rough in texture, in part crystalline, containing much silica, partly as masses or nodules of whitish translucent quartz and partly as angular fragments of the same	2	
17.	Limestone, yellowish, argillaceous, thin bedded, slightly undulating and weathering rapidly into marly clay	8	
16.	Limestone, hard, compact, yellowish grey, argillaceous; in layers four inches or less in thickness, lying in gentle undulations not more than a foot in height and about 22 feet from trough to crest	2	

		FEET.	INCHES.
15.	Limestone, non-magnesian, varying in color from light drab to dark drab and to brown; compact, hard and exceedingly fine grained as if made of finest calcareous silt; layers from nine to seventeen inches in thickness, somewhat irregular in structure and bedding; lying in broad low swells like No. 16; a few rare thin seams display a brecciated structure with calcareous fragments, like matrix, less than an inch in diameter. In all these layers *Spirifer subumbonus* Hall is gregarious	4	4
14.	Limestone, massive, yellowish, crystalline, weathering to reddish yellow	2	
13.	Limestone, ferruginous; weathering into thin calcareous plates yellowish brown in color, and traversed by thin vertical seams filled with calcite; layers from one-fourth to four inchs thick	2	6
12.	Similar to above but in two layers	1	4
11.	Limestone, brownish, weathering lighter and into thin plates	1	
10.	Limestone, hard, brown and crystalline; massive, but with distinct horizontal lines of lamination	1	4
9.	Limestone, hard, compact, brown; weathering to light greenish grey; briskly effervescent in cold dilute HCl; in places macrocrystalline, a fractured surface displaying little except the large rhombohedral faces of an impure brown calcite	1	3
8.	Limestone, magnesian; hard, crystalline, compact, grey; weathering into chipstone of irregular polygonal blocks a few inches in diameter	5	
7.	Limestone, hard, compact, light buff	1	
6.	Limestone, light brown, hard, briskly effervescent, irregularly bedded; layers about six inches thick	3	
5.	Limestone, hard, fine grained, compact, light grey; weathering to irregular layers one-half inch to four inches thick and passing into beds below	1	9
4.	Limestone, magnesian, soft, light yellow, granular, in layers one to four inches thick, not porous or vesicular: with some irregularly distributed cores of darker and harder limestone and also lenticular masses of chert with centers of dark grey flint arranged in thin horizontal layers	1	3

		FEET.	INCHES.
3.	Limestone as above, massive	1	9
2.	Limestone as above in thin layers		6
1.	Limestone, magnesian, massive; soft, light buff; somewhat argillaceous; containing small irregular nodules of chert with horizonta linear arrangement with abundant moulds and rare casts resembling *Spirifer subumbonus* above but generally smaller	4	

The Kenwood beds are represented in the upper three numbers of this section. Numbers five to fifteen constitute the Otis beds, while the lower four members may represent the Coggan beds. A little to the east of where this section was taken the *Spirifer subumbonus* layers become considerably thicker and also carry small irregular masses of black flint.

CEDAR RAPIDS SECTION.

About two miles west of the Otis quarry, above the mouth of Prairie creek, the Burlington, Cedar Rapids & Northern railway has scarped the upper part of a bluff on the west bank of the Cedar river and a quarry below the track continues the section nearly to the water's edge.

		FEET.	INCHES.
11.	Limestone, buff, argillaceous, weathering rapidly into a slope of marly clay and chipstone; some four harder layers each about six inches thick are interbedded and stand out from the slope in low relief	20	
10.	Limestone, non-magnesian	12	
9.	Limestone, light yellow, weathering to buff and reddish; breaking up into quadrangular blocks a few inches thick; layers one to six inches thick; contains many irregularly shaped dusty cavities often arranged in horizontal lines	5	
8.	Limestone, brown, with close thin lamination lines and bands of lighter color; briskly effervescent; in two layers	3	4
7.	Limestone, light buff, hard, compact, brittle, on mural surface displaying a network of perpendicular and diagonal cracks irregularly intersecting similar uneven horizontal cracks at intervals of a foot or less; in places weathering into thin layers from one-quarter to one inch thick	2	6

	FEET.	INCHES.
6. Limestone, brown, crystalline, briskly effervescent, irregularly bedded, with large, solid white calcite nests; much of the rock itself also crystallized in large brown rhomboids	1	2
5. Limestone, similar to No. 7	2	6
4. Limestone, brown, crystalline, similar to No. 6, lenticular below; upper foot thinly laminated	3	6
3. Limestone, light yellowish drab, magnesian; transition beds	1	
2. Limestone, moderately hard, light buff, magnesian; with some thin lenticular seams of black flint layers 6 to 8 inches; transition beds	1	2
1. Limestone, moderately soft, buff, magnesian with moulds and casts of fossils as at Otis, and some large concretions of black flint, eighteen inches in diameter, extending to within eleven feet of the water	6	

Of the above section, No. 11 represents the Kenwood beds, Nos. 3 to 10 inclusive the Otis, and Nos. 1 and 2 the Coggan. No. 10 is a variable member and a generalized description of several exposures along the track will afford a truer representation than a section at any one point. There are two lithological types embraced in it. The first, "A," is a hard, compact, non-magnesian limestone of finest grain and sub-conchoidal or splintery fracture, dark drab or brownish on first fracture, but weathering to light gray or white; often homogeneous and thinly laminated; often somewhat irregular in structure, occasionally containing in a limited area angular fragments of the same rock, which never exceed one-half inch in thickness. This type usually carries *Spirifer subumbonus* Hall. The second, "B" is a coarse, granular, crystalline, non-magnesian limestone usually massive, but sometimes becoming finer of grain and passing into thin layers. When massive it is especially characterized by a rudely concretionary or lenticular structure, the lenticular masses being twelve feet and more in horizontal extent. This rock is brown in color, but often on fresh surfaces displays a fantastic mottling with greenish yellow earthy spots. It also carries *Spirifer subumbonus*, the shells standing

in relief on weathered surfaces. It sometimes blends vertically within the compass of a hand specimen with the limestone of the first type. "A" is usually superior, occupying the hollows of the type "B". In one case type "A" thickens from zero on summit of lenticle to one foot on the side in a horizontal distance of four feet two inches. The lenticular masses, which sometimes are seven feet thick, are not arches or folds caused by lateral thrust, but are evidently due to causes affecting deposition. Sometimes type "A" is also inferior to type "B."

On the opposite side of the river, quarries along the Chicago & Northwestern railway have a fine, fissile, greenish clay one foot thick, at the base of the buff shale of number 11, underlaid by eight feet of thin layered drab limestone of the Otis beds. The Coggan beds do not appear further to the north on the Cedar river. From the mouth of Prairie creek to Cedar Rapids they dip gently up stream and pass beneath the river below the rapids to which the city owes its name and which are due to the change which there takes place from the soft and easily eroded strata of the Coggan beds to the harder strata of the Otis beds.

KENWOOD SECTION.

At Kenwood, on the right bank of Indian creek, is a fine cliff whose base is formed of the Otis beds, which lie here at nearly the same level as in the quarries just described.

		FEET.
6.	Breccia of small drab fragments with sparse matrix, including the Gyroceras beds of Calvin	11
5.	Limestone, massive, brownish, argillaceous and ferruginous; graduating in places into thin reddish plates and into shale; containing many angular siliceous fragments varying in size from sand to a few inches in diameter, and elliptical nodules, sometimes slightly laminated, the major axis reaching one foot in length; these consist of whitish translucent crystalline quartz. A microsection of a nodule from Fayette, identical in appearance, consists of interlocking crystals of quartz and calcite, the former being greatly in excess and containing many and large inclusions. The base of this bed simulates strong unconformity, sweeping downward into the shales below in broad curves and again rising until it nearly meets the breccia; where measured	15

Fayette breccia.

Kenwood beds.

Otis beds.

CLIFF AT KENWOOD.

		FEET.
4.	Shales, buff, calcareous; weathering into slope of marly clay; toward the top containing siliceous nodules and fragments, as in the beds above, and toward the base forming small argillaceous, laminated and fragile concretions	13
3.	Limestone, argillaceous, buff; thicker and harder layers, with bluish cores; also showing imperfect concretionary structure	2½
2.	Shales, thin, fissile, greenish	½
1.	Limestone, magnesian, thin layers, drab, dense; carrying *Spirifer subumbonus.* The layers are mostly from one-half to four or five inches thick. These are moderately smooth bedded, approximately parallel and lie in long and very gentle undulations. The thicker layers and sometimes the partings are slightly fragmental, the fragments being small, less than one inch in diameter, and a little darker than matrix	8½

The upper member of this section is the Fayette breccia. The shales and argillaceous limestones of numbers 2 to 5 inclusive are designated as the Kenwood beds, which form a distinct and well defined terrain throughout the county. The lower member represents the Otis beds.

YOUNG'S QUARRY.

To the northeast, up Indian creek, the strata rise, and at Young's quarry (Tp. 83 N., R. VII W., sec. 12, Nw. qr., Nw. ¼), the Otis beds extend to twenty feet above the creek, consisting of three fossiliferous layers, respectively one foot six inches, three feet and one foot thick, overlying five feet of thin bedded limestone without fossils.

MARION.

At the old Twogood quarry at Marion we have the following section:

		FEET.
4.	Breccia (exposed)	10
3.	Kenwood beds, thin bedded, shaly (exposed)	13
2.	Slope, rock unexposed	14
1.	Otis beds, with *Spirifer subumbonus*	6

The Otis beds extend unchanged nearly ten miles east of Marion, to within less than three miles of the Jones county line. A mile southeast of Springville (Tp. 84 N., R. V W., sec.

34, Nw. qr.) they outcrop at an elevation of over 100 feet higher than at Marion. Two feet of characteristic drab rock, traversed by vertical fissures and containing *Spirifer subumbonus*, overlie three or four feet of brown, ferruginous, crystalline, granular limestone, with drab flint nodules; of the latter phase the upper fifteen inches is massive and the remainder is in thin layers.

CEDAR RAPIDS.

Returning to the Cedar river sections, it is seen that the various beds described retain a nearly horizontal position from Cedar Rapids to a lime quarry, now disused, about two miles northwest of the city by the Burlington, Cedar Rapids & Northern railway track. The section here is:

		FEET.
4.	Kenwood shales, with quartz nodules, the lower foot being blue; above this buff	15
3.	Otis beds, massive with *Spirifer subumbonus* at base	6
2.	Same in thin layers, one-half to three inches thick	4
1.	Unexposed to level of track	7

Further to the south the characteristic irregularities of the Otis beds appear. The massive layer becomes lenticular and graduates horizontally into thin layers. Thin layers are flexed over it, thinning over the crowns, thickening in the hollows. Beneath number 2 of the above section appears a brown, thick, but irregularly bedded limestone.

From the lime quarry the strata dip to the northwest, and in a little over ten rods the Otis beds sink beneath the railway track, which descends in the same direction. The following section taken here at the southeast end of the railway cut repeats the familar succession:

		FEET.
5.	Breccia with abundant buff matrix; fragments few, of drab, finely laminated limestone, often rectangular in shape and sometimes nearly parallel but separated by matrix (Fayette breccia)	5
4.	Limestone, moderately hard, granular, semi-crystalline, buff, briskly effervescent and somewhat argillaceous; evenly bedded, gently flexed above, in layers from four inches to one foot thick; quarried for building stone (Kenwood beds)	16

		FEET.
3.	Limestone, brown, earthy, semi-crystalline; with a blue, hard limestone and a soft, coarse, granular and earthy limestone, dark drab or dark buff in color, often earthy when weathered. These are each extremely irregular and vary in thickness, but form one layer distinguished by the abundance of lenticular quartz nodules it contains (Kenwood beds)	6
2.	Limestone, light yellowish buff, thin, laminated, shaly (Kenwood beds)	14
1.	Limestone, light brownish drab, hard, splintery; even-layered, in layers two to four inches; flexed as seen further to the southeast over the irregular upper surface of a brown, massive limestone (Otis beds)	4

There are one or two other exposures of these beds along the Cedar river which may be mentioned. A little over two miles southwest of the railway bridge at Bertram, and the same distance west of the last outpost of the Le Claire at the Upper Palisades, the Otis beds form a ledge in a hill overlooking the flood plain of the river (Tp. 83 N., R. VI W., sec. 4, Sw. qr). The rock here is in places crowded with the common and only fossil of these beds. At the foot of the hill a buff magnesian limestone was once quarried.

A small quarry of the Otis beds on a hillside overlooking the old flood plain of the Cedar, about one half mile west of Otis, has its special interest in the curious intermingling of black flint with portions of the massive *Spirifer subumbonus* layer. Instead of being disseminated in nodules, it is aggregated in irregular columns and vertical leaves in a layer about a foot thick. The same layer was found in Cedar Rapids, in a sewer on Fifth avenue west, extending 120 feet west of Second street.

A hand specimen shows it to be quaintly mottled with impure black flint and grey limestone resembling in outlines the mottlings common in the more massive crystalline, earthy layers of the Otis beds (figure 14). Above this flinty layer were pockets up to two feet thick of dark fissile, non-calcareous shale and eight feet of thin bedded limestone. This has not been seen in place and the workmen could not say whether the shale reached the rock surface or not. Its position at once suggests

the greenish shale which forms th extreme base of the Kenwood beds. Its quality refers it rather to the coal measures, and similar clays belonging to a Carboniferous otlie areur found north of the city at Kenwood.

The most northern exposure of the Kenwood beds noted in the Cedar Valley is at the north end of the railway cut of the Chicago, Milwaukee & Saint Paul railway west of Linn, where a few feet of this shaly limestone are obscurely exposed at water level in river. They underlie, however, the Fayette

Fiaure 14. Dark flint and limestone from Fifth avenue sewer, Cedar Rapids.

breccia over the high prairie to the north, as is proven by wells, and emerge unchanged in the valleys of the Wapsipinicon and Buffalo. The sections along these rivers repeat in every detail the Cedar river section except that the Bertram beds are absent. The Coggan beds repose, therefore, directly upon the earlier formations.

At Coggan, the Coggan beds probably are in contact with the Pentamerus beds of the Upper Silurian, which have been noted as outcropping at higher level a short distance east of the

town. The following section taken at Ashby's quarry at the railway station will illustrate the character of the beds:

		Feet.
3.	Limestone, grey, hard, compact, sub-crystalline, magnesian; layers from one to four inches thick, weathering into block-chipstone	2
2.	Limestone, massive, pale buff, magnesian; moderately hard, granular, sub-crystalline; porous or vesicular, with a few irregular cavities about an inch in diameter; in layers from eighteen to twenty-four inches thick. These contain in abundance imperfect moulds, rarely casts, of a small spirifer-like shell indistinguishable from those at Otis, Cedar Rapids and Springville in beds attributed to this horizon. The lower two feet is variable. In places the rock weathers into chipstone, and is a brownish buff, semi-earthy, semi-crystalline limestone; thickness to quarry floor	8
1.	Slope to water in river, elsewhere seen to be occupied by massive limestone as above	6

A few feet above the level of the upper layers in Ashby's quarry the Otis beds are found adjoining the railway track north of the station. The layers here vary, become thicker and thinner, and mass in lenticles thirty feet long, but in a manner highly characteristic of this horizon. In general, the upper member is a hard, light yellowish drab, compact limestone, about two feet thick, with conchoidal fracture and in thin layers. Beneath this are five or six feet of varying brownish limestone. In places it is hard and compact, in places mottled, and earthy crystalline, composed of little angular fragments of hard limestone the size of coarse sand, with buff interstitial filling. Especially above, it tends to develop a black, flinty layer like that at Fifth avenue west, Cedar Rapids, in places passing into a vesicular, siliceous mass, resembling pumice. The total thickness of the section is about eight feet.

Less than half a mile north of Coggan the Mains quarry (Tp. 86 N., R. VI W., sec. 3, Sw. qr., Ne. ¼) exhibits some seven or eight feet of the Otis beds overlain by eighteen inches of interstratified greenish shale and thin, layered limestone with imbedded limestone fragments. The Otis beds here

are not so variable as at the railway station. The shales are found well developed in the adjacent cut of the Illinois Central railway. They are here five feet thick, highly argillaceous, somewhat calcareous, thinly laminated, and blue in color. Nowhere in the county is the green or blue shale at the base of the Kenwood beds in such force as here, and as it was believed to be the horizon of the Independence shales a most careful but fruitless search was made for fossils in the abundant debris along the sides of the cut. The shale is overlain by rough buff or purplish limestone, sandy with angular chert and quartz sand, and containing nodules of quartz and calcite. This is four feet thick, and its layers are from one to eight inches in thickness. It is succeeded by two or three feet of thin, calcareous plates and rough, dark-reddish limestone, covered by drift.

One and one-half miles east of Central City is an interesting section, where the base is clearly Niagara in contact with the Coggan beds above:

		FEET.
5.	Otis beds, with large masses of black, flinty limestone	6
4.	Slope, no rocks in place	10
3.	Coggan beds, abundantly fossiliferous, with the same fossils as at Coggan; lithologically similar, but much more cavernous; resting directly and apparently conformably on beds below	16½
2.	Limestone, magnesian or dolomite, compact, grey, crystalline, granular; friable, breaking into calcareous sand; made up of two upper layers in even courses four and five inches thick and a lower irregular layer about one foot thick resting directly upon beds below	1½
1.	Dolomite, fossiliferous as described previously (Niagara)	4

At Central City, as has been noticed, a dolomite unquestionably Upper Silurian, lies at the level of the water in the mill pond. At Finson's quarry, a quarter of a mile above the dam, there occurs, six feet higher, a vesicular, white, earthy limestone, and another which is more compact, weathering into polygonal fragments several inches in diameter. These are magnesian, but are not dolomitic, and in some respects resemble

the Bertram beds whose place they seem to occupy. They are some three feet thick, and are succeeded by the lower layer of the Coggan beds, a soft, earthy, magnesian limestone with the usual fossil moulds. A few rods further up the river a large quarry displays nearly the full thickness of the Coggan beds. The section taken here is as follows:

		FEET.	INCHES.
5.	Limestone, even-bedded, non-magnesian above, becoming more and more magnesian below, and so graduating by thin layers into the beds below that the line between them is somewhat arbitrarily drawn (Otis beds)	12	3
4.	Limestone, magnesium, light buff, compact, granular		10
3.	Limestone as above, darker, also non-fossiliferous excepting some minute vermicular cavities; in three layers	1	
2.	Limestone, massive, buff, magnesian; with moulds and casts of fossils, as at Coggan; porous and vesicular; upper layer cherty, with dark nodules forming in places a continuous band. The layers from above downward are respectively one foot, five feet and ten inches, eleven inches, and four feet ten inches in thickness	12	7
1.	Unexposed to river	10	2

Numbers 2, 3 and 4 of the above belong to the Coggan beds. These beds maintain their level to a fine exposure on the left bank of the river, two miles northwest of Central City, at Granger's old quarry (Tp. 86 N., R. VI W., sec. 28, Se. qr., Sw. ¼). The section shows their passage upwards into the Otis beds:

		FEET.	INCHES.
18.	Limestone, brecciated, unfossiliferous, composed of drab fragments, with abundant buff matrix in places	4	
17.	Limestone, buff, inclosing a few brown, angular fragments	2	
16.	Limestone, buff, earthy	1	
15.	Slope, with buff limestone fragments protruding in places	34	10
14.	Limestone, massive, buff and brownish mottled, with much calcite irregularly disseminated	1	9

		Feet.	Inches.
13.	Limestone, hard, grey, compact, crystalline; slow in effervescence		10
12.	Unexposed	3	
11.	Limestone, hard, compact, rather dark drab, weathering lighter and breaking up under atmospheric agencies into hard rhombic chipstone; layers two to four inches in thickness; briskly effervescent.	2	
10.	Limestone, hard, compact, light grey, saccharoidal, in layers five, seven and twelve inches	2	
9.	Limestone, hard, dense, non-crystalline, light yellowish drab in color, weathering into small chipstone with conchoidal fracture	2	
8.	Limestone, grey, highly crystalline, the rock as a whole having interrupted crystalline cleavages		6
7.	Limestone, drab, hard, dense, crypto-crystalline, weathering lighter, and into polygonal chipstone; fracture conchoidal, layers two to four inches thick	1	6
6.	Limestone, hard, brown, granular, crystalline, rough to the touch and briskly effervescent		11
5.	Limestone, dense, non-crystalline, of impalpable grain and conchoidal fracture, in thin laminæ	1	
4.	Limestone, hard, grey or light buff, minutely vesicular, especially the upper layer	1	1
3.	Limestone, hard, dense, crypto-crystalline, and non-crystalline; light and darker drab in color; in four layers, which weather into polygonal masses; resting directly and without apparent unconformity on the beds below	1	9
2.	Limestone, magnesian, soft, pale buff, of earthy lustre; in layers of six inches, one foot three inches, one foot two inches, and three feet three inches. The upper layer is more dense than those below, and contains minute vermicular cavities. None of the layers are laminated. They are highly vesicular, with cavities of the small, smooth-surfaced spirifer characteristic of these beds, and contain many irregular, dusty cavities up to an inch or more in		

		FEET.	INCHES.
	diameter. In these layers was found also the cast of a pygidium identified by Dr. Calvin as belonging to a small individual of *Dalmanites verrucosus* (Hall)	8	1
1.	Unexposed to water in river	21	1

Of the above section numbers 1 and 2 belong to the Coggan beds, numbers 3 to 14 inclusive represent the Otis beds and numbers 15 to 17 the Kenwood.

The exposure was first visited by the writer, and a section published, a number of years since, when stone was being taken out for bridge piers at Paris. It was then found that the layers of buff, magnesian limestone, now covered, extended to within ten feet of the water. The thickness of these from below upwards was noted as 31, 19, 27, 9, 9, and 5 inches. It was then supposed to be the only section in the state showing Silurian and Devonian strata in contact. The section has recently been republished by McGee,* together with a similar section at Fayette, Iowa. In the latter the massive, buff, magnesian limestones which underlie the Devonian strata are stated to contain fossil casts, and upon these must rest the question of the identity or diversity of these limestones with the Coggan beds.

In the above section all the courses are even and approximately horizontal, except where otherwise stated, and as in similar sections at Otis, Cedar Rapids and Central City no evidence of unconformity at any points was observed.

SAWYER'S QUARRY.

(Tp. 86 N., R. VI W., sec. 33, Ne. qr., Se. ¼.)

Here Otis beds were once quarried for lime. The succession is the same as so often noted:

		FEET.	INCHES.
3.	Kenwood beds	2	
2.	Otis beds in seven courses, upper layers of ten inches, with black flint as at Cedar Rapids, Fifth avenue west	16	8
1.	Unexposed to river	6	3

On a small creek to the west of the river (Tp. 86 N., R. VI W., sec. 33, Se. qr., Sw. ¼) are found some outcrops that supplement the section at Granger's quarry. The heavily layered

*Eleventh Annual Report U. S. Geological Survey, p. 315. Washington, 1893.

Coggan beds form a ledge near the river. Half a mile up the creek five feet of the upper layers of the Otis beds appear, rough, mottled and lithologically heterogeneous. They are overlain by a blue, calcareous shale four feet in thickness, which has been used experimentally for brick and found to burn white. This graduates into seventeen feet of typical buff Kenwood shales, with quartz nodules some nine inches in diameter. The buff shales merge into four feet of harder argillaceous limestone. They were tested by A. S. Hatch of Central City and found worthless for every economic purpose.

CEDAR BLUFF.

A little over three miles northwest of Granger's quarry, in a direct line, the bluffs on the right bank of the Wapsipinicon afford a number of fine sections. The one known as Cedar Bluff (Tp. 86 N., R. VII W., sec. 24, Ne. qr., S. ½) shows that the Otis and Coggan beds have both dipped beneath the river at this point.

		Feet.
5.	Limestone, fossiliferous, shaly; outcropping along a slope, apparently disturbed or brecciated (Devonian)	10
4.	Breccia, composed mainly of large fragments of hard, drab limestone, with some fossiliferous fragments	23
3.	Limestone, soft, earthy, dark buff, reddish; with angular cavities and with angular limestone fragments; the matrix constituting the main mass of the rock, passing downward into thin, calcareous plates a fraction of an inch thick containing botryoidal aggregations of spherical clayey concretions	17
2.	Limestone, soft, buff, with blue cores in lower layers, finely and evenly laminated	9
1.	Talus to water's edge, where a blue clay or shale occurs. Here, as at Granger's, quartz nodules occur in talus, but were not seen in place	4½

Number 4 is the Fayette breccia and numbers 1, 2 and 3 the Kenwood beds.

WOLF'S DEN.

At the Wolf's Den, about a mile up stream from Cedar Bluff, the Fayette breccia rests directly on thin, soft, and evenly laminated shales. The line of contact is uneven and

strongly suggests unconformity, but shale and breccia are so weathered that the alternative of slips along the scarp is possible. The base of the breccia is here seventeen feet above the water. Four miles further to the northwest, at Troy Mills, the Kenwood beds have sunk out of sight and the breccia occupies the channel of the river.

At a few points between the immediate valley of the Cedar and that of the Wapsipinicon, in the central part of the county, the Fayette breccia is cut through, revealing the Kenwood beds. They were noted on East Otter creek (Tp. 85 N., R. VII W., sec. 15, Nw. qr., Sw. ¼), Otter Creek township, and on Dry creek (Tp. 84 N., R. VII W., sec. 28, Se. qr., Nw. ¼).

RELATION OF COGGAN AND BERTRAM BEDS.

The lithological affinities of the Coggan beds are with the Silurian, and the three or four fossils hitherto found seem to be of Silurian types. The rock greatly resembles that of the Mount Vernon beds, differing in greater vesicularity and absence of lamination. It is further distinguished by the interposition of the Bertram beds between it and the Mount Vernon beds, in the central and southern portions of its outcrop.

It must be admitted, however, that the place assigned to the Bertram beds is somewhat anomalous. When the survey of the county was begun, it seemed at first probable that the Coggan beds were the westward extension of the Mount Vernon beds, while the Bertram beds were the eastward extension of the Otis beds. This hypothesis has the merit of simplicity and is supported by several considerations, chief of which is the absence of the Bertram beds in the Wapsipinicon sections, the other members of the Cedar river series being present and unchanged.

Nevertheless, the separation of the Otis and the Mount Vernon beds by the Coggan and Bertram beds is believed to be in accord with the facts for the following reasons:

1. The presence above the Bertram at Springville and on Big creek of a soft, buff, earthy, magnesian limestone (apparently as magnesian as the Coggan beds) with imperfect casts of fossils apparently identical in species and distribution with those

of the Coggan beds. Assuming the identity of this limestone with the Coggan, the subjacent position of the Bertram to the Coggan is proven. The Bertram beds have already been shown to be superior to the Mount Vernon beds. The only possibility of error in this argument lies in the fact that possibly the soft, buff, magnesian limestone lying above the Bertram at Springville and on Big creek may be decayed magnesian layers of the Otis, and that the imperfect moulds and casts found here have not been distinguished from those of a really distinct species in the Coggan beds,* or that the same species ranged from Coggan to Otis time and its presence in the two beds is not proof of their identity.

2. The absence in the Coggan of the fossils of the Mount Vernon and vice versa.

3. The difference between the Otis and the Bertram beds, which, when closely studied, becomes more and more apparent. In the former *Spirifer subumbonus* is found gregarious in every outcrop from southeast of Springville to the Cedar river. In the latter no fossils are found. The upper layers of Otis, whose entire thickness is less than the Bertram, are non-magnesian; the Bertram is magnesian throughout. The granular, crystalline layers of the Otis, often mottled and in part earthy, and containing black flint irregularly disposed, often lying in lenticular masses and alternating with thin layers of compact rock—these characteristic layers of the outcrop of the Otis in all parts of the county are entirely absent from the Bertram. In the absence in it of silica in any form the Bertram resembles the Le Claire rather than the lower Devonian limestones of Iowa. On the whole, also, the Bertram beds are more heavily and more evenly bedded than the Otis.

The force of these considerations compelled the relinquishment of the first hypothesis of the identity of the Coggan with the Mount Vernon beds and of the Bertram with the Otis, and the placing of them as distinct beds in the succession already stated.

* The species in question is a spirifer akin to *Spirifer modestus* Hall. It belongs thus to a type ranging from Silurian to Carboniferous, in which specific differences are inconspicuous in imperfect specimens.

DEVONIAN.

WAPSIPINICON STAGE.

The term Wapsipinicon has been suggested as an appropriate designation for the various lower beds of the Devonian series in Iowa, including as the superior member of the stage the Upper Davenport or Gyroceras beds.* The name indicates the exposure of the entire terrain in the gorge of the Wapsipinicon river from Troy Mills to Central City. The typical exposures, however, of the several beds of the terrain to which they owe their individual names are found elsewhere, along the Cedar and Mississippi rivers. The beds constituting the rocks of the Wapsipinicon stage are the Upper Davenport, the Lower Davenport, the Kenwood including the Independence shale, and the Otis. To these future investigation may add the Coggan. As the Upper and Lower Davenport beds are found in the county only in a brecciated condition they are here described under the name given to this brecciated zone, the Fayette breccia.

OTIS BEDS.

The lithological affinities of these beds are wholly with the Devonian, as has been seen in the detailed description of their many sections given in the preceding pages. They graduate downward by thinly bedded magnesian transition layers into the buff, heavily bedded magnesian limestone of the Coggan.

Spirifer subumbonus Hall, the characteristic fossil of the Cedar river sections (absent on the Wapsipinicon and Buffalo), is a well known Devonian species ranging through the Hamilton and Tully and into the Upper Chemung. The species in its typical form has not hitherto been found in Iowa. The specimens from the Independence shale, so named provisionally by Calvin, are stated in his description to differ from the type materially in size and in the width of the hinge area.* The specimens from the Otis beds are smaller than those from the Independence shales, their hinge area is narrower, the umbonal region of the ventral valve is more prominent and its beak higher and more recurved.

*Proc. Ia. Acad. Sci., 1893, Vol. I, pt. iv, pp. 23-24. Des Moines, 1894.

*Bull. U. S. Geog. and Geol. Surv., vol. IV, p. 729. Washington, 1878.

It is a very interesting fact that these beds which add a new and inferior member to the Devonian series in Iowa do not introduce any species of lower range than those which already constitute the Devonian fauna of the state. So far as the fossils of the Otis beds go—a fauna composed of one species in not a wide basis for induction—they ally them with the Devonian beds above rather than with any beds elsewhere representing epochs preceding the Hamilton. The line of separation between the Otis beds and the Independence shales is in most sections rather sharply drawn. The upper layers of the Otis represent disturbed sedimentation, but the transition is usually quite abrupt between the drab, non-magnesian limestones of the *Spirifer subumbonus* layers and the blue fissile shales at the base of the Kenwood beds.

KENWOOD BEDS.

The position and the nature of these beds define them, or at least their lower member, as the equivalent of the Independence shales. It will be remembered that the Independence shales were first discovered in a shaft sunk near Independence, and consisted of sixteen feet of fissile shale, dark and carbonaceous above, grey below, and carrying a rich and highly interesting fauna, which was fully described by Calvin. They were shown to immediately underlie the Gyroceras beds, and traces of a shale at this horizon have since been noted by the same authority at several points in Buchanan county. From rumors of coal found at various places along the eastern outcrop of the Devonian in Iowa, the generalization was made that these shales were not a merely local deposit, but constituted a widely distributed member of the Devonian series in the state. Subsequently the evidence supporting this conclusion was somewhat weakened by the discovery of Carboniferous outliers at some of the localities referred to from which rumors of coal had gone forth, and by the fact that no natural section of these shales had hitherto been found. Therefore, though the Independence shales have remained an accepted member of the Devonian series, any evidence of their extension beyond the place and county of their discovery is welcome. It is true

that the evidence in favor of the identity of the Kenwood beds with the shales of the shaft at Independence might be stronger. The former are destitute of fossils and carry no trace of carbonaceous matter. But the position of both, beneath the Gyroceras beds, and their argillaceous nature we must accept as proof that they occupy the same geological horizon.

The term Kenwood is therefore used in this paper only as a local synonym of the term which has the rights of wide acceptance and long priority.

Such a local synonym has seemed useful and necessary because of the differences which obtain between the shales in Linn county and those of the typical locality, because of their fuller development here, and especially since the exact parallelism of the Independence shales seems to be with the blue shale at the base of the Kenwood limestone and shales rather than with them as a whole. The Independence shales in their typical fossiliferous or carbonaceous phases have been found at two places in the county. Mr. E. N. Beach of Troy Mills states that a well dug west of Walker (Tp. 86 N., R. VII W., sec. 8, Se. qr., Ne. ¼) pierced a blue shale at a depth of one hundred feet. A fossil, *Strophodonta arcuata* Hall, was brought up by the sand pump and is now in Mr. Beach's possession. Crystals of pyrite are attached to the shell and it is filled with soft blue clay.

In 1877, as was reported at the time, a well sunk on the farm of Mr. C. Hemphill, near Lafayette, reached a thin seam of coal at a depth of ninety feet. This also belongs without doubt to the Independence shales, as the well mouth is upon or above the Fayette breccia.

FAYETTE BRECCIA.

The breccia which succeeds the Kenwood beds in Linn county is undoubtedly part of the brecciated zone which extends along the eastern outcrop of the Devonion from Davenport at least to Fayette, at practically the same horizon. In Linn county it is believed that the clastic forces were at a maximum; the breccia is thickest here and best displays its

characteristic phases. In this county several distinct lithological and faunal stages are involved, which it may be well to state before giving in detail any farther sections of it. The brown or buff, earthy, ferruginous and quartziferous limestones of the upper Kenwood not infrequently contain sparse, angular, limestone fragments, and pass upward into a breccia in which the buff matrix is abundant and often contains angular, siliceous sand. The included fragments are small and few. This constitutes the first and lowest stage.

Figure 15. Fayette breccia of first stage from Granger's quarry, Central City.

A second stage is that in which drab fragments, usually small, constitute the bulk of the breccia, the softer buff or grey matrix being for the most part interstitial. The fragments are composed of a hard, dense limestone, light or dark drab in color, ringing under the hammer, compacted of impalpable and pure calcareous silt, and breaking with smooth conchoidal or subconchoidal fracture. The rock in its original state was to a large extent thin layered, as may be seen from the irregular rectangular shape of many fragments. They also often show finest and close lamination lines picked out by weathering, but the laminæ remain firmly cemented together. These lines are

apt to be undulating, contorted or sharply flexed, or even concentric. This limestone resembles some of the layers of the Otis beds that bear *Spirifer subumbonus.* A theory of the formation of the breccia might possibly be framed which would admit the presence of fragments of the Otis limestone as clastic sediments in the breccia, despite the intervening Kenwood shales. But it is more probable that a lowering of the sea floor

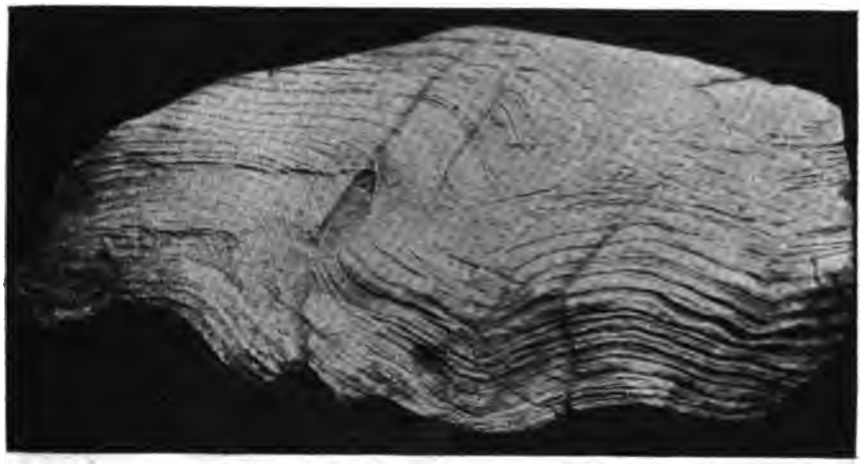


Figure 16. Contorted laminæ in breccia fragment of second stage; from below Robins.

at the close of Kenwood times allowed again the deposition of pure calcareous silt. If the fragments in question were derived from the Otis, in which *Spirifer subumbonus* is so abundant in the Cedar valley, it seems hardly possible that among the many thousands of fragments of this type scanned, none should have been found fossiliferous. The brown crystalline limestone of the Otis is also absent from the breccia. The thin layered, drab, non-magnesian, non-fossiliferous limestone which we believe was deposited upon the Kenwood, and whose fragments constitute the bulk of the breccia is not found undisturbed in Linn county. It is identical with the thin layered, partially brecciated, unfossiliferous limestone occupying this horizon, exposed along the Mississippi from Davenport to Gilbertsville. To avoid repetition of descriptive terms, the limestone which forms the fragments of the second stage may be called the

Lower Davenport type. Although the Lower Davenport beds have been wholly broken up so far as seen in Linn county, large masses are occasionally found which themselves contain rectangular fragments of laminæ of the Lower Davenport type, which still remain approximately parallel and horizontal though separated by a grey matrix. Such a mass from west of Linn Junction is figured below.

Figure 17. Fayette breccia illustrating complex brecciation and parallelism of fragments; from west of Linn.

In this stage brown fragments of the upper Kenwood are also sometimes present.

A third well defined stage is that in which large fragments, often several feet long, of heavily bedded, tough, grey, semi-crystalline limestone predominate. These carry a distinct fauna in which *Pentamerus comis*, Owen, and *Orthis macfarlanei*, Meek, are the most common, and a large Gyroceras and *Rhynchonella intermedia*, Barris, the most characteristic fossils. Other forms are *Strophodonta nacrea*, Hall, *Proetus haldemani*, Hall, and teeth of *Ptychtodus calceolus*, N. and W. This is the Gyroceras bed as defined by Calvin in Buchanan county, and is

believed to be the equivalent of the fossiliferous beds at Davenport attributed by Barris to the Corniferous. The matrix resembles usually the matrix and fragments of stage four, and fragments of this upper stage are often found interstratified or in juxtaposition.

A fourth stage is defined by the absence or comparative rarity of fragments of the preceding stages. Matrix and fragments are composed of fossiliferous shaly limestone of the type of the ordinary fossiliferous shaly Cedar Valley limestone at Independence, Vinton, Davenport and many other localities along the eastern outcrop of this formation. This stage embraces the *Spirifer pennatus* beds and often the higher coralline beds as defined by Calvin in Buchanan county. Frequently it constitutes a true breccia, the fragments being of moderate size and tilted at all angles. It is often, however, disturbed but not brecciated, much of it occupying its original horizontal position, with here and there fractures and tilted blocks of large size. On natural sections where it has weathered to a slope covered with fragments, it is extremely difficult to determine the extent to which the beds have been disturbed. This stage includes several biotic zones which will be considered elsewhere.

The stages just defined are not parted by any fixed and constant horizontal boundaries. The forces producing the brecciation of these beds were sufficiently powerful to commingle the strata to a certain extent, and it is only in a broad way that the divisions suggested may be made. They have been found useful in the field and can often be recognized at a glance.

On account of its passage upward into slightly brecciated or disturbed fossiliferous limestone of the ordinary Devonian types, and on acconnt of the fact that in the fourth stage brecciation is not constant, it is difficult to map the area of the Fayette breccia. It may be said to extend from the northern to the southern limits of the county. Its eastern outcrops are between Central City and Paris, at Flemingville and Marion. Its western outcrops as the country rock are near Troy Mills, Lafayette and at Linn. West of these points, at Alice Post Office, Ward's quarry (Tp. 85 N., R. VIII W., sec. 24, Se. qr., Nw.

¼) and Toddville, we have the unbrecciated beds of the Cedar Valley limestone which will be discriminated elsewhere by their fossils.

The following are a few representative sections out of many which may be taken within the area mentioned:

Section on north road from Paris to Troy Mills (Tp. 86 N., R. VII W., sec. 16.)

		FEET.
4.	Breccia of drab fragments (second stage) slightly fossiliferous at top	14
3.	Limestone, rough, brown; with angular cavities resulting probably from dissolution of non-magnesian fragments; sandy near base	12
2.	Shale, Kenwood	13
1.	Limestone, hard grey, Otis	2

Section at Eidemiller quarry (Tp. 85 N., R. VII W., sec. 15, Nw. qr., Sw. ¼).

		FEET.
4.	Limestone, disturbed fossiliferous beds (fourth stage)	4
3.	Breccia of tilted blocks, some being six feet long, of hard grey limestone, with abundant *Pentamerus comis* and with large Gyroceras (third stage) passing into breccia of abundant drab fragments (second stage)	14
2.	Breccia with abundant buff matrix	2
1.	Slope to flood plain of east branch of Otter creek	18

The Kenwood beds are exposed near water level a short distance from this point on the opposite side of the creek.

Hemphill's section on West Otter Creek (Tp. 85 N., R. VII W., sec. 18, Ne. qr.).

		FEET.
3.	Breccia, fossiliferous (fourth stage) some layers horizontal, some tilted at all angles, no small fragments of Lower Davenport type present	6
2.	Breccia, (second stage, Fayette type), composed mostly of fragments of Lower Davenport limestone, usually small, mostly an inch or so in diameter, rarely over six inches, many finely laminated and laminæ sometimes flexed; matrix buff, small in amount, at the base some large fragments of soft bluish grey limestone, one to three feet long, and apparently little disturbed	23
1.	Unexposed to water level	3

In the cuts of the Chicago, Milwaukee & Saint Paul railway between Cedar Rapids and Marion, the structure of the lower breccia may be studied to advantage, though the sections are in no place over eight feet thick. The rough, reddish brown limestone of the Kenwood emerges occasionally in a low broad arch. From the breccia above, hand specimens can be obtained containing siliceous angular sand, fragments of the Lower Davenport type, and of the *Pentamerus comis* or Upper Davenport rock in the same buff matrix. Above this, large blocks of the third stage are seen. A few boulders of sandstone are found, probably belonging to the Marion Carboniferous outlier.

MARION.

At a quarry within the city, north of the cemetery, the basal member of the breccia is exposed for fourteen feet. The fragments here of the Davenport type are rather small, any over six inches being conspicuous and rare. No fossils are found in either fragments or matrix. The matrix is too abundant to be interstitial. It is grey or buff in color, and soft, weathering rapidly so that the imbedded fragments can be easily disengaged with the fingers. At the top, for an area of six feet in horizontal dimensions and four feet vertical, fragments are quite absent, leaving a rough, brown, vesicular, limestone irregularly bedded and with undulating laminæ.

At the south end of the quarry for over twenty feet at the base there is exposed a buff limestone four feet thick, massive on the whole, but showing irregular laminæ in places. This contains very few fragments and is practically undisturbed. Yet it passes into breccia at the same level. In this quarry some of the fragments were evidently derived from the upper layers of the Kenwood.

TROY MILLS.

An interesting horizontal section of the breccia of the second stage is found at the river's edge below the bridge. The matrix here is slight in amount. In certain areas—the largest area noticed was seven feet long—a buff non-fossiliferous limestone was deposited apparently in hollows caused by the unequal

aggregation of the larger fragments. This contains a few angular fragments constituting not over twenty-five per cent of its bulk. The fragments in the breccia as a whole are unusually large. Fragments a foot in diameter are common and many are several times as large. One ten feet long was noticed, composed of the laminated limestone of the Lower Davenport type. The size of the constituent fragments renders especially distinct a characteristic feature of this stage, many of the fragments being themselves brecciated, consisting of drab fragments in a grey unfossiliferous matrix.

LINN.

In some respects the best exposure in the state of the Fayette breccia is along the cut of the Chicago, Milwaukee & Saint Paul railway on the Cedar river west of Linn. The line along which, with some interruption from ravines, the breccia stands exposed to the heighth of ten to twenty-five feet above the rails, is some three-quarters of a mile long. The total vertical exposure is about sixty feet, the grade of the railway rising from twenty feet above the river at the south end to fifty-nine feet above it at the north.

The breccia exposed at the south end is some twenty-one feet thick, its base being twelve feet above low water level in the river. The matrix here is scanty, soft, and yellow or grey in color, occasionally arenaceous with angular fragments of quartz perhaps derived from the Kenwood beneath. The fragments are mostly small and of the Lower Davenport type, though some are seen several feet in diameter. Occasionally toward the base a fragment occurs of thin, laminated, brownish crystalline limestone like some of the upper layers of the Kenwood. In two or three places near the summit fragments of the *Pentamerus comis* limestone occur, and here also was found a small quartz nodule with vesicular surface, similar to those plentiful in the Upper Kenwood. A portion of the base is but partially brecciated and consists of a rather soft, whitish grey crystalline limestone, saccharoidal in texture varying to semicrystalline and yellowish grey, with a few inclusions of angular fragments of the Lower Davenport type. There are traces in

the limestone of low arches thirty or forty feet long and three feet high.

A transverse valley about one quarter of a mile wide separates this cut from the next exposure of the breccia at a higher level in a ledge twenty-one feet high. The lower part of the ledge is made of contiguous fragments of the Lower Davenport type and some larger blocks of Upper Davenport limestone containing *Pentamerus comis,* with fewer fragments of shaly, buff limestone of the fourth type, all commingled in the most heterogeneous manner conceivable. Above, the fourth type predominates and in places along the top of the ledge is apparently little disturbed. Even here, a few small angular fragments of the Lower Davenport type are imbedded in buff shales. This horizontal distribution is not constant. Masses of breccia of the second stage rise in places to the summit, alternating with other masses in which a soft, yellow, arenaceous, non-fossiliferous matrix is especially abundant, and the breccia weathers back several yards from the face of the cliff adjacent and forms a talus of two-thirds its height.

Further to the north, as the track ascends, the zone of the third or Upper Davenport stage is well marked by huge blocks in which *Pentamerus comis* is abundant. The larger ones are tilted somewhat, but seem to retain something of their original attitude. One measures eleven feet in length and two feet six inches in thickness. The vertical surfaces of these blocks commonly show slickensides of shallow grooves, usually at about right angles to the bedding planes, trenching rock, thick Pentamerus shells and sections of fossils alike. One block was observed in which this massive grey crystalline limestone graduated at the base into a thin layer of the typical Lower Davenport limestone.

Towards the north end of the cut the breccia of the fourth stage becomes predominant, though fragments of the other types are still present. In places towards the summit, however, they are quite absent and well defined fossil zones may be traced, *Spirifer bimesialis,* Hall, yielding percedence to *Spirifer pennatus,* Owen, and continuous coralline layres in a harder limestone appearing, with *Phillipsastrea billingsi,* Calvin, and *Acervularia davidsoni,* E. & H.

These coralline layers form the summit of the section at the extreme north end of the cut.

At Linn Station, breccia of the third stage is exposed and excellent examples of this and of the fourth stage may be seen in a cut on the Burlington, Cedar Rapids and Northern railway oue-half a mile south.

CEDAR VALLEY LIMESTONES.

In this limestone several life zones may be drawn, distinguished more by the general assemblage of their fossils than by the presence of any species elsewhere absent. Immediately succeeding the Gyroceras or Upper Davenport beds lies a zone often involved in the Fayette breccia, marked by the abundance of three species: *Orthis impressa*, Hall, in forms intermediate between *O. macfarlanei*, Meek, and *O. iowensis*, Hall; *Stropheodonta demissa* in small rugosely striated shells of protean forms, approaching, if not including, *S. plicata*, Hall; and *Spirifer bimesialis*, Hall, in its typical form and in a new variety with wider area. Less abundant but still more characteristic is an *Orthothetes*, sp., nov. Associated with these are the following species so far as now determined:

Atrypa reticularis, Linn.
Atrypa aspera var. *occidentalis*, Hall.
Cyrtina hamiltonensis, Hall.
Crania crenistriata, Hall.
Orthis iowensis, Hall.
Orthothetes chemungensis, Conrad var., nov.
Pentamerus comis, Owen.
Pholidostrophia nacrea, Hall.
Productus subalatus, Hall.
Stropheodonta demissa, Conrad, typical form.
Stropheodonta inequistriata, Conrad.
Spirifer fimbriatus, Conrad.
Proetus haldemani, Hall.
Phillipsastrea billingsi, Calvin.
Goniophora, Sp. undet.

To this succeeds a stage in which the more distiactive spirifers are *S. pennatus*, Owen, *S. asperus*, Hall, and *S. undiferus*,

Roemer. With these are associated most of the species named above. *Orthis macfarlanei* gives place to *O. iowensis* in large transverse, flaring shells. *Stropheodonta demissa* assumes its typical form. Orthothetes disappears. *Phacops rana*, Green, occurs. The two Atrypas are found in greater proportional numbers. To this or to the zone below belongs *Pentamerella micula*, Hall, and a large Chonetes of the species for which Calvin has announced the name cancellata. In the upper part of this zone occurs a reef of *Acervularia davidsoni*, E. and H., with many favositoid and cyathophylloid corals. At Robins it overlies the Orthothetes zone and at Ward's quarry, Center Point, and at Alice P. O. it overlies beds barren of fossils. At Troy Mills it is succeeded by the hemera of *Spirifer parryanus*, Hall, the highest life zone discriminated in the county.

CARBONIFEROUS.

The Marion outlier belonging to the Carboniferous is described by the writer*. Coal and sandstone are reported to have been found also on the farm of Mr. Wm. Reynolds on west Otter creek, and are reported to lie on fossiliferous Devonian limestone. As the black carbonaceous shale was reached at a depth of six feet from the surface, it probably belongs to the coal measures and not to the Independence shales. To the same horizon probably belongs a greenish shale, with crystals of selenite, disclosed in a transverse ravine lying uncomformably upon the breccia in the Chicago, Milwaukee & Saint Paul railway cut west of Linn. A pocket of light greenish and bluish, unctuous, plastic clay in Conklin's quarry at Mount Vernon is probably Carboniferous, or possibly Cretaceous. It occupies irregular nests or cavities in the Mount Vernon beds, burrowing between layers and being intercalated between the laminæ adjacent, and connecting with a chimney reaching from top to bottom of the quarry. The narrowing base of this chimney is filled with a saccharoidal sandstone. The clay contains aggregations of pisolitic concretions of carbonate of lime. In its position and nature it is quite similar to the pockets of fire clay at Clinton, Iowa, described by Farnsworth†, now considered by

*Iowa Geol. Surv., vol. III, pages 127-128. 1895.
†Am. Geol., II, 331-334. Minneapolis, 1888.

him as Carboniferous. Neither at Mount Vernon nor at Clinton is there any trace of Pleistocene deposits in the clay.

CRETACEOUS.

Limestone boulders with Cretaceous fossils have been found in the drift at Mount Vernon and west of Walker. The distance which these had travelled cannot be told, but a perfect belemnite found in clay at a depth of forty feet (Tp. 87 N., R. VII W., sec. 21, Ne. qr., Se. ¼) and now in the possession of Mr. E. N. Beach of Troy Mills, must have been near its original home. So slender a fossil could not long have resisted attrition in the southward moving ice and drift. Its presence three miles north of the county line suggests the possible presence of Cretaceous outliers in Linn county also.

EXPLANATION OF PLATE.

In plate iii are represented three geological sections across Linn county as follows:

Figure 1. *a–b* Section from Cedar river near Bertram to Stone City.
Figure 2. *c–d* Section from Toddville to Mount Vernon.
Figure 3. *e–f* Section from mouth of Big creek to Cedar river west of Linn.

The numbers used refer to the different beds as follows: 1, Le Claire; 2, Mount Vernon; 3, Bertram; 4, Coggan; 5, Otis; 6, Kenwood; 7, Fayette breccia; 8, Cedar Valley; 9, Drift; 10, Loess. The horizon of the Independence shale is between the Otis and Kenwood beds.

PLEISTOCENE.

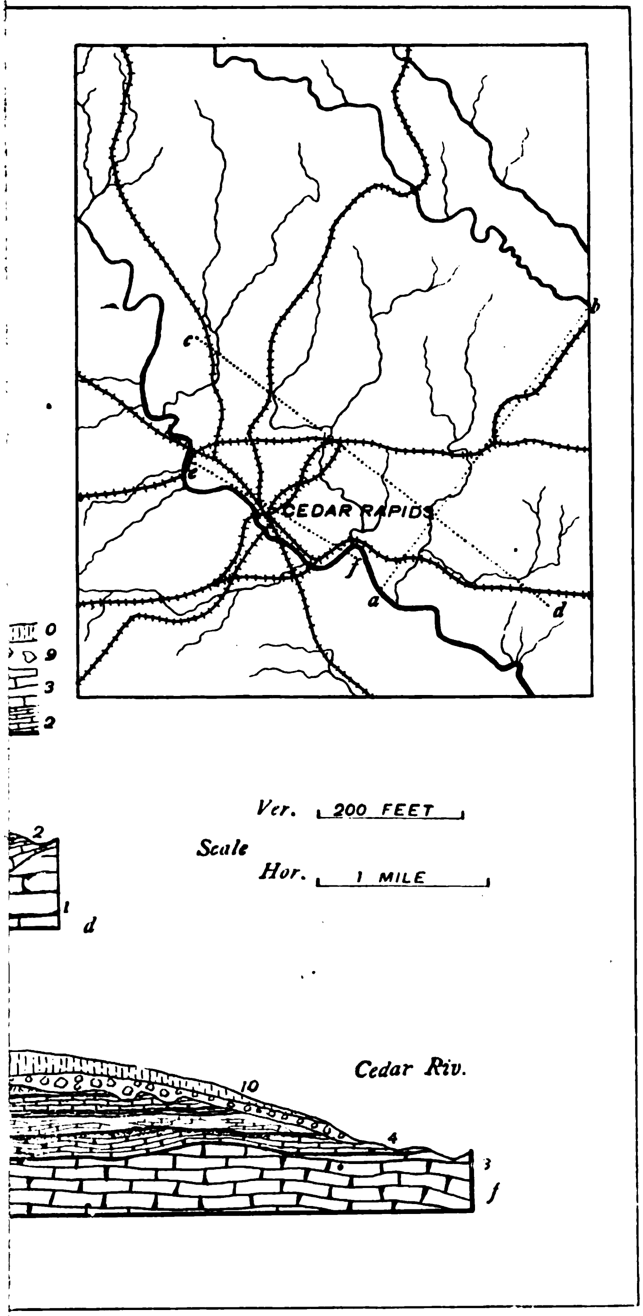
DEPOSITS.

The history recorded in the deposits of this period is in this area particularly complex and interesting. It has recently been so thoroughly interpreted by McGee* that only supplementary notes need be given here. The deposits which will be considered include, from the surface downward, the following beds:

1. Alluvial sands and silts.
2. Loess.
3. Pre-loess sand and valley drift.
4. Second or Upper till.
5. First or Lower till.

*Eleventh Annual Rept. U. S. Geological Survey, 190-577. Washington, 1893.

PLATE III.



6. Residuary clays.

These will be considered in the inverse order.

RESIDUARY CLAYS.

In all parts of the county the rock is more or less deeply decayed beneath the lowest layers of the drift. Irregular depressions, pockets, pipes and chimneys, mark the rock surface, descending sometimes to a depth of twenty feet or more and lined with an exceedingly fine, unctuous, black or brown residuary clay. This geest is seldom more than a few inches thick, and when the cavities in the rock are of any considerable width their centers are filled with drift. The anomaly of the presence of these preglacial clays and rotten rock in the very track of the ice sheet, is but little lessened by the fact that when the ice plow passed over them they must have been firmly cemented by frost.

THE KANSAN DRIFT SHEET.

First or Lower Till.—This is an unstratified, calcareous, stiff blue clay containing sand, pebbles, and boulderets of the northern igneous rocks with some of limestone and many of residuary flints and cherts. The pebbles are occasionally glaciated and larger stones are often found faceted and striated. Its base is often sandy and gravelly; when in this condition it is one of the chief water-bearing horizons in the county, and is then reddish or brownish in color. In the loess-capped drumloid aggregations of till in this region which McGee has called paha, the first till is sometimes roughly horizontally or concentrically laminated, though from other causes than the sorting power of water. In the railway cut across the north end of the Mount Vernon paha hill, these laminæ are from one to three inches thick.

The thickness of this till varies from zero to nearly two hundred feet. It is exposed in but few places in the county, but it may be seen in the railway cut of the Illinois Central railway between Coggan and Central City; at Peacock's tile factory at Coggan, south of Viola where it is superficial over quite an area; at Conklin's quarry, Mount Vernon, and at Kirkpatrick's mill three miles south of that village. It often contains fragments of wood, especially towards the base.

THE EAST IOWAN DRIFT SHEET.

The Second Till.—This boulder clay resembles the first till in the following particulars:

1. In lithological and structural diversity.
2. In the presence of calcareous meal.
3. In the predominance of clay over coarser ingredients.
4. In the abundance of glaciated pebbles, proving it subglacial and not englacial till.
5. In the abundance of decayed pebbles, distinguishing it from the till of the northern moraines, the East Wisconsin drift sheet, absent in the county.

It may be distinguished from the first till:

1. By its yellow color. When taken fresh from wells, it is distinctly brighter than loess, more yellowish and less buff; and it retains this color even to a depth of eighty-five feet from the surface, and beneath blue or greenish clays. It must therefore be regarded as a deposit distinct from the first till and not derived from it by superficial postglacial weathering.
2. By the presence of larger stones and of boulders*.
3. By the comparative rarity of limestone and chert pebbles.
4. By the beds of sand and gravel at its base, which form one of the main water horizons of the county.

The upper portion of the second till is often more loose in texture and may be englacial. Sand occurs in discontinuous and tortuous veins, as if laid down upon a pitted, irregular and water-washed surface before the deposition of glacial till had entirely ceased. The attitude of the upper sands simulates sometimes, as in the Mount Vernon quarries, a crumpling by superincumbent ice. The upper limit of the till is often marked by a line of more abundant pebbles, some of which are faceted and striated. Above this line nothing is found coarser than the sand of the succeeding member of the series, the pre-loess sands. The second till accentuates the relief of the

*The largest boulder entirely imbedded in till was found in Conklin's quarry, Mount Vernon. It is composed of granite, is over eight feet in length and 512 cubic feet in bulk. It rested on a basal planed and striated surface, inclined at an angle of about seven degrees toward the southeast. The lower edge is separated from the rock by from four to six inches of yellow till. The northwestern end was separated from the adjacent till by a cavity two or three inches wide, evidently caused by the slipping downward and forward of the stone after deposition. Some streaks of sand surrounded the stone as if laid down by water eddying about it.

surface left by the first ice invasion as is seen in the sections of the Mount Vernon paha given below. That it is the product of a later ice invasion and not derivative from the first till by weathering is seen in the fact that its accretion upon the hills of the first till is not regular and uniform; the summits of the hills of the one not corresponding exactly with the summits of the hills of the other. No traces of a forest bed have yet been found in the county in this till or beneath it at its juncture with the first till. The thickness and bulk of the second till are probably less than that of the first and if any conclusion may be drawn from the scanty evidence at hand, it is more attenuated in the Wapsipinicon than in the Cedar valley.

Many of the large boulders of the county probably represent, in part, the englacial drift of the second ice invasion. A large proportion of those now exposed to view may have once been imbedded in the till of the ground moraine. When erosion has been most active and where the loess mantel is absent in the swales and intervales of the drift plains, boulders are therefore most common. No boulder belts or trains have been observed.

THE PRE-LOESS SANDS.

Along the periphery of the paha hills the deposits made by ice are succeeded by waterlaid sands and gravel. While these probably need not be considered as a distinct formation, they no doubt mark a special state in local Quaternary history. The term which is used seems preferable to "sub-loess sands," inasmuch as the loess was not everywhere deposited above them, but it is perhaps objectionable in that it distinguishes them too sharply from the loess into which they often grade. In origin they seem intimately connected with the wash of the till by the water of the melting ice sheet and with the fluvio-lacustrine conditions and slack drainage of the loess epoch which followed. The accumulation of these sands on the outer slopes of the hills of boulder clay which form the centers of paha, and their absence in the interiors and on the summits of these hills, together with their thickening toward the water courses where they merge into valley drift, prove

that they were not laid down by glacial streams confined within canyons of ice, but are more akin to the overwash sands of morainic areas. Coarse and gravelly beneath, especially in the neighborhood of waterways, they become finer above and are interstratified with bands of darker clayey sand or sandy clay which become closer, wider and more loamy until they pass into the loess.

VALLEY DRIFT.

Heavy accumulations of silt, sand and gravel occur in the immediate vicinity of the streams of the county, and may be taken as a measure of the volume and swiftness of the floods which occupied these channels at the close of the second ice invasion. The following section at Bertram near the mouth of Big Creek is typical of much of the valley drift of the county.

		FEET.
5.	Loess-like loam	3
4.	Sand, interstratified with sandy clay	4
3.	Sand, finely and horizontally stratified, fine above, growing coarser below	30
2.	Sand and gravel with cobble stones	3
1.	Slope of fine, whitish clay, to water in creek (probably marginal)	6

In the gravel pit of the Chicago & Northwestern railway across the creek from the above section, number two is seen to rest on rock, and between it and number three intervenes a layer two to three feet thick, of fine, whitish clay, with many well preserved twigs and branches of coniferous wood. In stream ways of the smaller creeks and their branches the following deposits are often seen:

4. Black humus, up to four or five feet thick, often reddened at the base by ferruginous accumulations.
3 Fine, bluish-grey, non-calcareous clay of equal thickness with the above.
2. Gravel and cobblestones from the drift, often faceted.
1. Till.

Numbers two and three are evidently valley-wash, accumulated before the soil above them. They are not the product of the present streams which, in many instances, were not in existence a few years since. The digging of a ditch a few inches in

depth breaking through the protecting mattress of roots in the swale, or invasion by a subsequent branch from the primary creek by head-water erosion has led, in a score of years, to the trenching of gullies several rods in width and as much as eight or ten feet deep. Often near the head of the narrowing gully a tiny waterfall is seen trickling over the edge of number three, thus visibly continuing the process of retrocessive erosion. In heavy rains the gully is well nigh filled with running water, producing extensive washouts in its sides and bottom, and sometimes bringing to light teeth of the mastodon or mammoth or bones of the buffalo. These washouts cause a serious loss to the pasture lands of the county and should be stopped by the planting of willows.

THE LOESS.

The loess of Linn county may be described under three phases. The first and lowest phase is a fine silt, ashen or drab in color, though sometimes stained with hydro-ferric oxide. "Bulls eyes," ferruginous and calcareous tubelets, and "loess-kindchen" are common, and it is to this phase that the experienced observer looks first for fossils. It graduates beneath into the pre-loess sands when these are present, and it is often interstratified with thin veins of white sand. In the interior of paha hills it graduates upward into loess of the second phase, but on the margin the two phases are sometimes sharply separated by inter-laminated yellow sands and sandy clay, as at the railway cut at Mount Vernon, and the Wolf brick yard at Cedar Rapids. It usually is more strongly calcareous than the phases above. The second phase is typical yellow or bright buff loess, pulverulent and vertically cleft. Neither fossils nor loess-kindchen are common. It graduates downward either into loess of the first phase or by interlamination into the pre-loess sands. It constitutes the bulk of all thick exposures of loess in the county.

Above, it passes without any well defined lines of demarkation into the third phase—a browner, finer, non-indurated loess loam, drying into small blocks a fraction of an inch in diameter which are not readily friable between the fingers. It is usually marked by narrow, parallel, uudulating bands, somewhat

darker and harder than the remainder because of ferruginous accumulations. These are most plainly seen after rains, on account of the hygroscopic differences in the clay, and always dip with the slope of the hills. This phase is derived from the second by weathering, and it may also represent differences in deposition, the final stage in a progressively finer sedimentation. It is superficially modified in the humus layer and forms a soil of admirable agricultural qualities.

At the following localities the loess was found to be fossiliferous: "Point of Rocks," southeast of Ivanhoe bridge, Cedar River; railway cut at Mount Vernon; Cedar Rapids, on creek south of Peedycoats' brickyard; Big Creek, in Tp. 83 N., R. VI W., sec. 26, Sw. qr., Nw. ¼.

PREGLACIAL EROSION.

The relief of the county at the close of preglacial times was due to many factors, chief among which were, (1) the inclination of strata; (2) the varying resistance to detrition of the different geological formations, giving a higher relief to the most obdurate like the Le Claire, and a lower tothe softer like the Independence shales; (3) deformations of strata affecting or reversing normal dips, and (4) continental movements of the earth's crust. Little is now known of the relief of the county at the beginning of the glacial epoch. There is a considerable amount of evidence showing that the channels of preglacial drainage were to a large extent the same as those at present.

In the valleys of small creeks and of rivers alike, numerous sections show the drift sheets and loess mantle lying undisturbed on the sloping sides of rock cut valleys, descending perhaps to the water's edge and to the lowest base levels of erosion. That such valleys must have been excavated before the tills were laid down upon them is evident. When the first till is present, the erosion cannot belong to the interglacial epoch, preceding the second ice invasion.

When the rock surface is deeply decayed and overlaid with geest, the erosion must be preglacial. In some instances the rivers have been turned slightly aside from previous channels,

but are still well within their ancient valleys. In Cedar Rapids, on the west side of the river, a buried channel sixty feet deep has been found by Mr. H. G. Hays, separated from the present rocky bed of the stream, by rock rising nearly to the level of the low broad flood plain on which this portion of the city is built.

At Central City, an old channel of the Wapsipinicon is disclosed by wells on the east side of the village. It is separated from the present channel by a rocky elevation that comes within a very few feet of the surface of the low plain on which the village stands. The following is a section of a well sunk in this ancient channel on the premises of Mr. Cutler.

		FEET.
2.	Black soil	4
1.	Sand, fine yellow, to rock	96

From the maps of the U. S. Geological Survey and from a general knowledge of the locality, it is estimated that the depth of this ancient channel is at least sixty feet below water in the river. The following section of a well on the farm of Mr. P. G. Henderson (Tp. 86 N., R. VI W., sec. 17, Nw. qr.) apparently reveals an ancient channel of the same river, about three-quarters of a mile north of the present streamway:

		FEET.
7.	Black soil	4
6.	Clay, yellow, pebbly, second till	15
5.	Sand, yellow	4
4.	Clay, blue, changeable from hard to soft every few feet	190
3.	Sand, fine white	13
2.	Sand, coarser with wood	12
1.	Coarse gravel	3

No continuous preglacial waterways, apart from the present paths of the streams, have been traced. Though such exist, they are deeply buried by drift and no surface indications of them appear.

The drill disclosed such a buried channel on the farm of Mr. Joseph Smyth, three miles west of Mount Vernon, were rock was reached at 211 feet; 110 feet below low water in Cedar river. (Tp. 82 N., R. 6 W., sec. 12, Se. qr., Se. ¼). The following is the well section:

		FEET.
7.	Loess	14
6.	Clay, hard blue, pebbly; first till	48
5.	Wood and dark soil	6
4.	First till	66
3.	Sand and gravel	8
2.	First till	63
1.	"River sand"	6

TERRACES.

The following section made from special survey of the immediate valley of the Cedar at Ivanhoe bridge is a typical representation of the ancient flood plains of the Cedar.

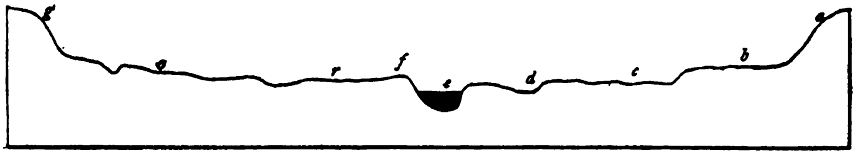


Figure 18. Flood plains of the Cedar river at Ivanhoe bridge.

In the above, *a* and *g* are loess-mantled hills, whose full height is not here represented; *b* is a level terrace with steep sides, as well marked as a railway fill; it is twenty feet in height and its summit is thirty-five feet above low water stage in the river. It is covered to its outer edge with typical pulverulent loess. As it is hardly possible that a terrace of this width could be so uniformly covered with loess derived by creep or wash from the adjacent hills, the formation of the terrace must be as assigned at least as early a date as the closing stages of the second ice invasion. A quarry, in a continuation of this terrace to the south, shows rock, covered with about six feet of soil with loess, covering pebbles of the northern drift imbedded in geest. The quarry is near the river edge of the terrace and is separated from the hill by a shallow ravine. *C* is a flood plain not now reached by river floods and with a long and very distinct scarp some nine feet in height separating it from the present flood plain of the river at *d*. *E* is the river, and from *f* to *g* a flood plain which seems to be degraded by erosion from the level of *b*. The terrace at *f* is composed of stratified sand, showing in places beautiful oblique lamination

and sandy brownish clay, passing downward into coarser sand and gravel at its base.

DISTRIBUTION OF PLEISTOCENE DEPOSITS.

Linn county lies in what McGee has aptly termed the "land of the paha"—the aboriginal term for the lenticular hills and elongated ridges whose gentle loess-mantled slopes and inflexible northwest-southeast trend make the landscapes of this region as distinctive as they are unique. The position of these long swells was no doubt determined by the preglacial surface, but of this too little is known to warrant any more definite conclusions. Their trend marks the direction of the flow of the ice beneath which their nuclei were moulded, as clearly as the longer axis of the sand bar marks the direction of the current of the river.

In describing their distribution in the county, it will be convenient to speak of the paha hill, the paha ridge and the paha belt.

CENTRAL DRIFT PLAIN.

From Paralta to Viola and from Marion and Toddville to the divide within one or two miles of the Wapsipinicon river, stretches without interruption a gently southwestward sloping plain formed of drift. A typical well section near Paralta shows that the drift forms only a thin veneer over the rock surface.

		FEET.
3.	Black loam	3
2.	Second till	7
1.	First till to rock	14

The first till seems to constitute the bulk of the drift and occasionally becomes superficial. The surface is scarcely diversified except by the drainage channels which are sunk to sixty or eighty feet below the broad and level inter-stream areas.

THE PAHA.

Bordering the drift plain just mentioned lie two paha belts of hilly country crossing the county parallel and adjacent to its largest rivers. The southern or Cedar paha belt is complex and embraces several paha ridges. Of these the most southern passes through Ely. Its maximum elevation

above sea level is 880 feet and above adjacent streamways 140 feet. Its greatest breadth is a little over one mile. Another ridge enters the county at Fairfax from Benton, in which county it has its maximum development. A heavier paha ridge, which may be named from Cedar Rapids, occupies the immediate valley of the Cedar. To it belong the almost continuous hills on the right bank of that river from the southeastern corner of the county to Covington, and on the left bank the hills at the Palisades and those from Bertram to Linn Junction. Thus defined its greatest width is about four miles and its greatest height 940 feet above sea level.

The Lisbon paha ridge has its greatest extension in Cedar county. It extends through Mount Vernon to the high hills south of Marion where it joins the Cedar Rapids paha. Its greatest width in the county is about one and one-half miles. At Mount Vernon it is 932 feet above sea level and about 250 feet above Cedar river.

The Marion paha ridge begins a little northwest of Marion and extends through Robins and Toddville to the Benton county line. An adjacent and parallel ridge on the left bank of the Cedar south of Centre Point may be considered as a part of this. Its greatest elevation is at the western end, 940 feet above sea level.

The Stanwood paha ridge is separated from the Lisbon paha by a well defined plain three miles in width, sloping gently westward and drained by Abby creek. To the east, rock lies within from twenty to thirty feet of the surface of this plain, but to the west the drift upon it is a hundred feet thick, or more. Though nearly level to the eye when viewed from the paha, it consists of billowy till, some of whose crests are covered with loess. At its highest points the Stanwood paha ridge is 960 feet above sea level and measures one hundred feet from base to summit. At its northern extremity at Big Creek it connects by intervening paha hills with the Paralta paha ridge, which extends southeastward from this point into Jones county.

The hills of the Paralta ridge are less directly connected than those of the ridge before mentioned. The highest stands

960 feet above sea level and 140 feet above the streamways adjacent to their bases.

The Wapsipinicon paha belt may be considered one ridge whose axis is cleft by the Wapsipinicon river, so narrow is the valley that at Central City and at Waubeek, separates the paha hills on either side of the stream. It is highest southwest of Waubeek, where it reaches the height of 1,040 feet above sea level, or 200 feet above the flood plain of the river and nearly half as much above the drift plain to the south.

At Waubeek the portion of the ridge situated on the left bank is specially massive, forming a plateau stretching three miles northeastward to the Buffalo. Beyond the Buffalo a drift plain extends to the county limits. A typical section of this plain is given by McGee* from Prairieburg, where the drift is reported to be composed of fourteen feet of first till carrying vegetal matter, overlain by sixteen feet of second till.

Structure of the Paha.—So little has been published of the structure of these unique relief forms, so recently defined and described, that the following sections of paha in Linn county, though few in number, are of special interest.

The first well section, on the farm of Mr. W. Jordan, (Tp. 85 N., R. VI W., sec. 24, Sw. qr., Sw. ¼) is taken on the crest of the highest hills south of the Wapsipinicon about 1,000 feet above sea level, and 180 feet above the flood plain of the Wapsipinicon, two miles north.

		FEET.
7.	Black soil	6
6.	Clay, yellow, almost clear of grit	20
5.	Blue clay, pebbly	38
4.	Clay, yellow, mixed with sand	5
3.	Clay, blue, with a few feet of muck	152
2.	Whitish clay	2
1.	Lime rock	1
	Total	224

About twenty rods west, on still higher ground, the well of Mr. L. D. Jordan gives the following section:

*Eleventh Ann. Rept. U. S. Geol. Sur., p. 532. Washington, 1893.

		FEET.
7.	Black soil	4
6.	Yellow clay	15
5.	Blue clay, pebbly	14
4.	Sand and gravel with some water	6
3.	Blue clay "of all kinds"	75
2.	Quicksand	15
1.	Gravel	4
	Total	133

A section from the top of a lower paha hill of the same ridge is afforded by a well at Mr. G. W. Wiggins (Tp. 85 N., R. V. W., sec. 20, Se. qr., Nw. ¼).

		FEET.
3.	Soil and loess	12
2.	Pebbly blue clay with wood	23
1.	Gravel	4
	Total	49

Two wells at Coggan on the summit of the high hill at whose foot is Peacock's tile kiln show the hill to be composed mostly of the first till. In the F. P. Rice well, 128 feet deep, the blue boulder clay is 100 feet thick; and in the Shaw well, 100 feet deep, it is eighty feet thick. The following section is of a well on the crest of the Paralta paha about 920 feet above sea level on the farm of Mr. Wm. Paul (Tp. 83 N., R. V W., sec. 9, Sw. qr., Sw. ¼).

		FEET.
5.	Loess	27
4.	Sand and a little gravel with water	3
3.	Blue pebbly clay	45
2.	Sand and gravel	12
1.	Rock	2
	Total	89

The following is near the crest of the high paha south of Lisbon, on the farm of Mr. P. J. Fisher.

		FEET.
6.	Soil and loess	28
5.	Hard, yellow, pebbly clay	36
4.	Dark, pebbly clay, about as hard as rock	53
3.	Clay, hard, blue, pebbly	10
2.	Sand and gravel	1
1.	Rock at	128

A well on the farm of Mr. J. Hoffman (Tp. 82 N., R. V W., sec. 23, Nw. qr., Se. ¼) gives a section on the southern margin of the same paha.

		FEET.
6.	Yellow loam	14
5.	Blue silt	4
4.	Hard, blue, pebbly clay	28
3.	Dark soil and wood	4
2.	Sand and gravel	1
1.	Rock	1
	Total	50

The hill upon which Mount Vernon is situated is a typical paha, in shape, in form, in orientation, and it is believed in structure also. The latter is so diverse that it can be represented by no one well section. Numerous records of recent drillings are fortunately at hand which allow the presentation of the longitudinal and transverse sections represented in plate iv. which will be found more intelligible than any description. Though not here distinguished, the three phases of the loess are present, the lowest being fossiliferous in several wells and excavations, and in one well found to contain twigs of coniferous wood. The absence of the pre-loess sands except on the margins will be noticed.

The second till is clayey throughout, containing few, if any veins of sand or gravel except at or near its base. The gravel of these basal layers, when gravel is present, is fine.

The greenish, pebbly clay at Dr. Boyd's well in the section is as hard as the second till and differs from it only in color so far as appears in the drillings. In several wells it occurs in thin streaks or lenses, in the midst of second till, of normal bright yellow color. The first till contains wood as seen at the base at the College Library well.

The figure 4, plate iv, is a section across the northern flank of the paha. The angle of the slope is exaggerated with the exaggeration of the vertical scale.

The lower six inches of the brownish buff upper loess, 5, are perceptibly sandy. The sandy layers, 4, are slightly undulating, yellow in color, from a fraction of an inch to a foot or more in thickness, thickening outward and downward and growing

slightly coarser beneath. The interlaminated sandy clay or clayey sand is darker in color, varying from buff to brown. The drab silt, 3, is finely interlaminated above with thin veins of white sand, but the layers of silt grow heavier beneath and are found as much as two feet thick. They carry fossils of the loess.

EXPLANATION OF PLATE.

In plate iv are represented several sections through the Mount Vernon Paha. They are as follows, the letters representing the location upon the accompanying contour map, plate v.

Figure 1. Transverse section along the line a-b.
Figure 2. Transverse section along the line c-d.
Figure 3. Longitudinal section along the line e-f.
Figure 4. Section at railway cut, west end of Main street.

In figures one, two and three the numbers refer to the formations as follows: 1, Limestone; 2, Lower till; 3, Upper till; 4, Greenish pebbly clay; 5, Loess. In figure four the numbers refer to the beds as follows: 1, Lower till; 2, Upper till; 3, Fossiliferous drab silt; 4, Interstratified sand and sandy clay; 5 and 6, Loess passing upward into humus.

ORIGIN OF PAHA.

Taking it for granted that the sections given above are typical, it is seen that paha are essentially hills of subglacial till accreted in the direction of the ice flow. They are therefore genetically akin to drumlins, though their elongation in ridges is far more marked. The loess increases their height, but it is regarded as secondary in importance. Hills of characteristic paha form exist in the county, upon which there is no reason to believe that loess was ever deposited. The Wapsipinicon paha ridge on the right bank is destitute of loess from Troy Mills as far south as Paris, but it maintains its bold elevation above drift plain and river and its singular northwest-southeast trend. It is as marked a topographical feature as any paha ridge in the county, although its slopes are less gentle. It is composed entirely of drift, the total thickness of which must be about one hundred feet. A well section (Tp. 86

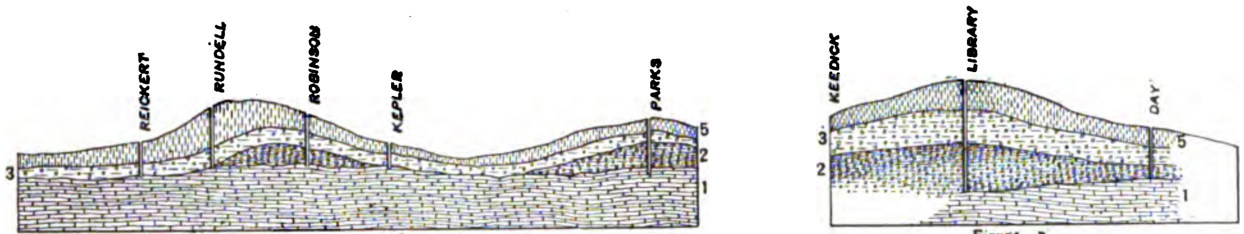


Figure 1. *Figure 2.*

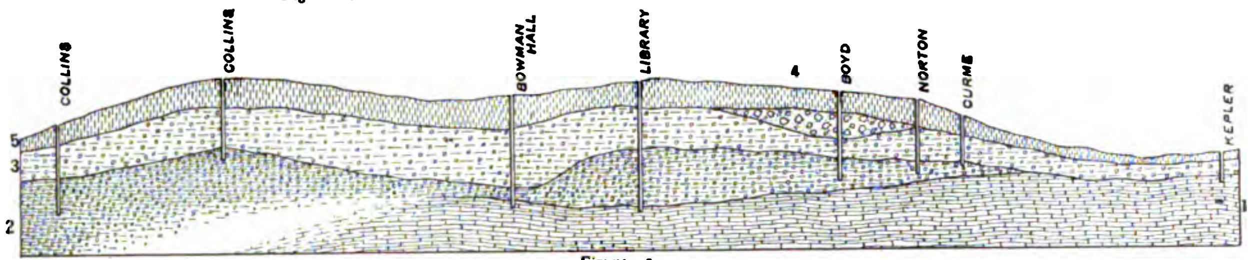


Figure 3.

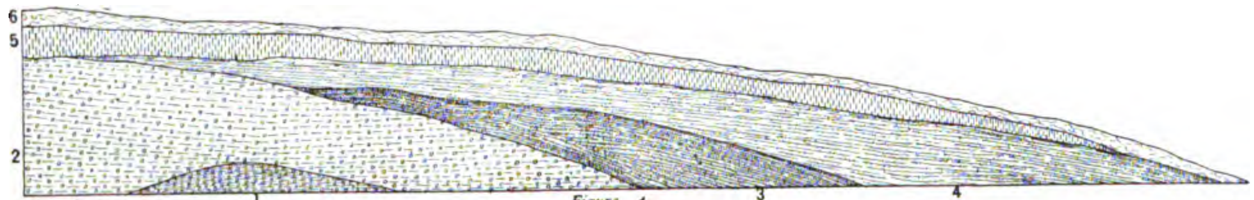


Figure 4.

SECTIONS THROUGH THE MOUNT VERNON PAHA.

N., R. VII W., sec. 16, Se. qr., Sw. ¼), considerably beneath the summit of the ridge gives seventy feet of second till with some sand and gravel overlying the rock.

The drift of these anomalous ridges and hills cannot have been deposited in ice-bound canyons by subglacial and superglacial streams. The absence in the drift of water-washed material, of sands and gravels, to any greater extent than obtains in the drift sheet of the same region precludes their classification with asar or eskers. Their distribution must also be considered. Isolated paha hills are numerous, connecting the different ridges. If these were formed by glacial waters, it must have been by moulins rather than by rivers. Yet their parallelism with the system is conspicuous. The linear courses of the paha ridges are devoid of the sinuosities characteristic of asar. This will be best seen by comparing a map of any large asar region, like Maine, with the topographical map of northeastern Iowa.

Neither can the paha be correctly spoken of as "eskers of loess"*.

The distribution of loess in the county is indeed peculiar. It is the thickest on the highest summits. It thins toward the valleys where it is often absent. But in either paha belt the loess-mantle is practically continuous, except in the immediate vicinity of the streams. The ridges are connected not only by terminal merging and by isolated intervening paha hills, but also by a thin layer of loess on the crests of many of the low swells of drift intervening between the paha within the area of the belt. If the loess of the Cedar paha belt, for example, were deposited between walls of ice, the walls must have been eight or ten miles apart, so remote as to have been without influence in moulding the loess of individual ridges or hills.

If an ice-walled canyon be invoked for the moulding of the loess of each ridge and detached hill a further difficulty is met. It can hardly be conceived that the ice sheet was so devoid of englacial and superficial drift that sand and gravel, to say nothing of larger stones, would not have been mingled with the river silts within the canyon. Yet in the many hundreds of

*Upham. Bul. Geol. Soc. America, Vol. V., p. 95. 1894.

exposures of loess observed in the county, no pebbles or boulders have been seen and the loess is free of sand except at its base.

On the other hand, by the hypothesis of the deposit of the loess of any paha belt in a broad, slowly moving current, the ridges of till beneath the water surface, by locally retarding the current, would accumulate silt bars about them. If the final retreat of the waters was somewhat rapid, either owing to the breaking of an ice dam, or accelerated by a comparatively rapid resilience of the area, much of the valley loess may be conceived as being swept downward with the retreating waters. The detrition of the soft silt remaining must have gone on with special energy until it was finally protected by the return of grasses and forests. These considerations, and the vast lapse of time since the loess epoch, lead to an account for the thickening of the upland loess by differential erosion and deposition as stated.

This theory does not account for the absence of the loess mantle over the wide central drift plain overlooked by the paha on either side. Had such a mantle ever been laid down, some remnants should be left along the north-south axes of the creek divides. Its absence here must prove that it was never deposited over the area, and the ingenious theory of McGee that such drift plains were covered in loess times by ice seems to be the best explanation to the phenomena.*

ECONOMIC PRODUCTS.

BUILDING STONES.

MOUNT VERNON BEDS.

The chief quarries of building stone in the county are in the Upper Silurian limestones of Stone City, Waubeek and Mount Vernon. This stone is so uniform that the general description

*Special acknowledgements for data supplied for this portion of the report are due to the Department of Civil Engineering of Cornell College, whose levels of the region about Mount Vernon were freely placed at disposal of the Survey and by whose students the contour map of Mount Vernon and several of the profiles were specially prepared without charge. Indebtedness is also heartily acknowledged to the intelligent co-operation of several well drillers in the county—Messrs. E. Kemp, West and Woodring, and C. Martz, of Mount Vernon; Messrs. Stewart and Dunlap, of Springville, and Mr. A. H. Gillilan, of Central City.

given in the preceding pages applies with little modification to each quarry in the county, if not in the state. It is necessary only to emphasize here a few points relating to its economic qualities.

The color of the stone is pleasing. Its warm grey or cream tint is accordant with nature's scheme of landscape colors. It is not so glaring or so sombre that it is out of key with the color of wood, lawn and street. Its cheerful warmth, the absence of dull leaden, or pale dark grey tints, harmonize with the rich colors which prevail under Iowa skies. The softness of the stone when just taken from the quarry, before the quarry water is evaporated and the lime and magnesia in solution have set, renders it easily worked. The saw encounters no obdurate materials; the chisel finds the fracture even and regular. Bedding planes are so constant, parallel and smooth as to be at once ready for mortar with little or no dressing. Much of the stone can be split horizontally to desired dimensions. Many layers are sufficiently tough and homogeneous in texture that they can be wrought into fine carvings. It is distantly jointed and blocks beyond the facilities of transportation or possible uses can be quarried.

In durabilility the Mount Vernon limestone is believed to be excelled by none of the calcareous building stones in Iowa and by but few in the United States. The fineness and uniformity of its grain allow no inequalities in ratios of expansion under changes of temperature. Injurious minerals which by their ready decomposition stain and weaken many otherwise excellent building stones are absent.

As a dolomite it resists the attack of atmospheric agencies more successfully than pure limestones and marbles. In the Mount Vernon cemetery, tombstones of this material, whose dates run back as early as 1845, are so little affected by superficial decay, that the tool marks are almost as fresh and sharp as when the chisel left them, and there is no sign of checkage, cracks, exfoliation and other evidences of internal disintegration. On the other hand, many marbles of less than half their age show weathering in loss of polish, ready detachment of superficial grains, and obliteration of fine edges, and deeper

decay in checks and fissures which predict a ruin not remotely distant. In the case of some of the earlier and poorer marbles, and of the oölitic limestones of the Lower Carboniferous this ruin has already been accomplished. Thus the humble dolomitic memorials of the first settlers bid fair to outlast every monument now in the cemetery except the granites.

The strength of the stone varies somewhat, that of finest grain and laminæ being probably weaker than the layers of coarser grain. The latter are sufficient for any strains and stresses, and the former have ample strength for any building of a height which would probably be erected in the state. Layers in which the lamination is specially distinct and which would be durable when laid in an ordinary wall on their "natural beds," should not be used for curbstones, where exfoliation would be likely to occur. Layers occasionally are found in which hard laminæ alternate with softer porous and vesicular ones. These cannot be recommended as durable. The form of dressing known as "quarry-faced ashlar," either "coursed" or "random range" is specially suited to this stone.

STONE CITY QUARRIES.

CRESCENT QUARRY OF BROWN & COMPANY.

The following detailed section of this quarry, the best developed in the county, will illustrate the stratification of the Mount Vernon beds:

		FEET.	INCHES.
17.	Loess, drift and geest	4	
16.	Rubble	18	
15.	Bridge stone, can be capped at almost any place	3	8
14.	Dimension stone in two layers	2	4
13.	Bridge stone; can be capped in middle; vesicular	2	9
12.	Limestone; hard, compact, with slightly salty effervescence; breaking readily into rhombic chipstone a few inches in diameter; called flint by workmen, although destitute of silica		6
11.	Dimension stone		4
10.	Dimension stone	1	
9.	Dimension stone	8	4
8.	Bridge rock, will not cap except at 24 inches from top	2	9

		FEET.	INCHES.
7.	Dimension stone	6	4
6.	"Flint rock" as No. 12	1	6
5.	Dimension stone	4	5
4.	Bridge stone	3	6
3.	Bridge stone	2	
2.	Dimension stone	3	4
1.	Unexposed to water in river	27	

The bridge stone contains in some layers a few small cavities filled or lined with quartz or calcite, or with both, the former being then exterior. These do not affect the value of the stone and are of interest only to the geologist. The eighteen feet of rubble of No. 16, includes eight or ten feet that in smaller quarries would probably be sold for local building stone. The quarry is but recently opened, and as it is driven back this thickness will probably be added to the amount of dimension stone. The natural facility for handling the stone here is unusually good. Stripping is comparatively little and is readily dumped into the river. The stone is lowered and loaded on the railway cars by gravity. The dip of the rocks here is 2°, E. 17° N.

WAUBEEK QUARRY.

The stone quarried here is indistinguishable in color and texture from that at Stone City. The most important quarry is that of Mr. C. A. Huston. The quarry face is about forty feet high, and the quarry floor is about twelve feet above low water in the river. The upper four or five feet are weathered into thin spalls below which the even courses are from a few inches to four feet in thickness. As no railroad is near, the output is restricted to local uses, though the stone is practically unlimited in quantity and its quality is of the best.

MOUNT VERNON QUARRIES.

The same limestone at Mount Vernon differs from the stone described at Waubeek and Stone City only in a somewhat warmer color, slightly coarser grain and perhaps a somewhat greater toughness. Lack of facilities for shipping has hindered the development of the quarries here, as the stone has to be carted about one mile to the railway station. Since these are the only quarries of the Mount Vernon beds along the main

line of the Chicago & Northwestern railway, it is probable that the abundance of excellent stone they contain may in time secure a switch*. The property has recently passed into the hands of Messrs. Platner, Gregg & Kirby. They have, within a year, put in the most complete and expensive quarry plant in the county, embracing a steam channeling engine, steel derrick, two steam planing engines and a steam crusher.

The stripping in the main quarry consists of a few feet of loess and clayey upper till, a little residuary clay in pockets and depressions, and about eight feet of spalls. Beneath these thin layers are several layers six to eight inches thick, and the following succession of layers to the quarry floor: 1 foot, 10 inches, 2 feet, 10 inches, 6 inches, 1 foot, 6 inches, 1 foot, 2 feet 11 inches, 2 feet 4 inches. No chipstone layers are found and no cherty nodules or silica in any form occur.

To test the thickness of this building stone, borings were made with diamond drill to a depth of fifty feet beneath the present quarry floor. The cores show that to that depth the above stone continues unchanged, mostly in heavily bedded courses. A few layers, however, show thin alternating hard and soft laminæ. The last few inches of the cores indicate a near approach to the lime rock of the Le Claire. The local dip is 3°, S. 37° W. The market is local and along the Chicago & Northwestern railway. The adaptability of this stone to large and fine structures is illustrated in the chapel of Cornell College, constructed in 1878 of stone from this quarry at a cost of $70,000.

Mr. William Conklin owns a quarry of similar stone which shares the local market with the quarry just described. At the quarry of Anton Novak, west of the Ivanhoe bridge across the Cedar, the stone, while in several layers similar to that at Mount Vernon, is in other layers highly vesicular, less evenly bedded, and destitute of lamination. In some layers flat, lenticular concretions of chert form almost continuous bands. Interbedded layers of a compact, darker rock occur which weathers into rhombic chipstone. This quarry furnished the stone for the piers of the adjacent bridge.

*Since the above was written, tracks have been built from the Mount Vernon station and the quarries greatly enlarged.

COGGAN BEDS.

These beds, like those which have been described above, are dolomitic. They are heavily bedded, destitute of lamination, and often porous and highly vesicular. Where cavities are few and of small size this stone is well adapted for heavy masonry, and has been used for bridge piers at Coggan, Central City and Paris. The quarries of these beds have been already described.

BERTRAM BEDS.

Except on a few farms the Bertram stone is not quarried. Its brittleness and habits of weathering, as well as locally heterogeneous structure, render it unfit for masonry.

OTIS BEDS.

Some lower and even layers of these beds are quarried at Otis, Central City and other points, for cellars, well curbing and other similar purposes. In general the stone is fit only for macadam, for which purpose it is quarried at Cedar Rapids.

KENWOOD BEDS AND FAYETTE BRECCIA.

Some harder layers near the top of the Kenwood and the Gyroceras beds of the breccia have been quarried to a slight extent at Marion, near Cedar Rapids and near Flemingville. If the latter, or Upper Davenport limestone, existed undisturbed in any thickness in the county it would prove one of our valuable building stones.

CEDAR VALLEY LIMESTONE.

This stone is often too shaly to be of much use as a building stone. As a rule, it soon breaks up under the alternations of wet and dry and of heat and frost. The bedding is not smooth or even, and it is covered by oblique fracture-planes which make it impossible to quarry blocks of any considerable size. Certain barren beds beneath the *Acervularia davidsoni* life-zone furnish a better stone, which is suitable for foundations for small buildings. The best quarries are George Ward's, four miles southeast of Centre Point, from which that town obtains much of its stone, Todd's quarry at Toddville, Peter Mack's at Alice postoffice, and Fay's quarry at Troy Mills.

DRIFT.

The boulders of northern drift, though seldom so plentiful as to interfere with agriculture, are sufficient to furnish foundation stone for many barns and farm houses. In some instances granite boulders of large size have been broken up for dressed stone.

CLAYS.

CHARACTER AND DISTRIBUTION.

Valuable clays are everywhere present in the county and are of several kinds, which will be briefly mentioned.

Loess.—The loam of this ancient fluvio-lacustrine deposit makes, when properly handled, an excellent building brick of sufficient hardness and density, and of a fine cherry red color. The best brick clay is found in the upper stratum of the loess. This stratum thickens at the base of loess hills and here brick yards are usually placed. The clay here is finer, tougher, browner, usually finely jointed on drying, and banded with ferruginous stains.

Sand is obtained in the same pits from the sandy loess beneath. In mixing the sandy layers with the upper stratum, the experience and judgment of the burner is followed. The mistake of using too much sand for the sake of ready handling is more common than the opposite one of using too little, especially in yards where the brick are hand made and sun dried. A soft, porous brick results, which must be handled with the delicate attentions appropriate to bric-a-brac, and which goes to pieces if left out over the winter unprotected, and when in the wall develops in a few years a seriously seamy side on the weather face.

In machine brick the quantity of sand can be lessened. The upper stratum of the loess can be used quite pure, although it is said to work better when mixed with the pulverulent loess beneath, or with a little sand or coal ash. An excellent smooth faced brick, though somewhat brittle, is made from this layer by machinery now in use in the county. Some pressed brick made by a Boyd brick press in Chicago from clay in the upper loess taken from the Wolf yard at Cedar Rapids leaves little to

be desired in their hard, smooth faces, and even and sharp edges. On low ground adjacent to loess hills, a stiffer, partially decolorized clay derived from the loess is found, which makes excellent tile.

Drift Clays.—Where drift is of the clayey type in which boulders and pebbles are comparatively few, it makes a harder and denser brick than the average loess-loam. The presence of pebbles of any considerable size or to any extent in such brick produces a heterogeneous texture and introduces an element of weakness. The upper or yellow till is better adapted than the lower or blue till when equally clayey, since, though it contains larger boulders, limestone pebbles are not so common. These burn into quick lime, and unless previously crushed, rupture or weaken the brick on slacking. In this class may be included slough clays, or gumbo washed from the drift. These are stiff, often gritty, sometimes pebbly in their passage into the drift, and make excellent brick and tile.

PLANTS IN OPERATION.

Cedar Rapids.—The plant of S. Peacock and Son is the largest in the county, consisting of an engine of twenty-five horse power, a stiff-mud brick machine, the Auger mill No. 5, of Nolan and Maddan's make, with a capacity of 15,000 brick per day, drying sheds holding 150,000 brick, and two circular, down-draft kilns. The clay used is the loess, mostly from the upper layer, and makes a smooth-surface brick of superior appearance.

Mr. P. A. Wolf uses also the loess-loam, making a brick the excellence of which is well attested by experience. A "Chief" soft-mud machine with a capacity of 30,000 per day is used, employing horse power. Drying sheds built on the Pullet system are employed and have a capacity of 100,000. The brick are burned in two clamp kilns, with coal and soft wood.

Mr. J. S. McKee also manufactures largely for home market. He uses the loess-loam to a depth of about three and one-half feet, mixing with it sandy soil and hard coal screenings in definite proportions. The machine used is the Old Reliable hand press, with a capacity of 10,000 per day. The capacity of the drying sheds is 50,000.

Mr. J. L. Peddycord uses a reddish drift clay so strong that it is tempered with the sand which overlies it, and burns into a hard, firm brick. No lime pebbles were noticed, though others of the ordinary drift type are not uncommon. A Quaker horse power machine is used, capacity 18,000 per day. The brick are sun dried and burned in a clamp kiln with soft wood and coal.

Mr. D. W. Stookey operates a tile plant consisting of steam engine, crusher, a Brewer and Tiffany machine, capacity 10,000 three-inch tile per day, three drying sheds and two circular, down-draft kilns, each of 150,000 capacity. The clay used is slough clay or gumbo, passing into drift. A switch of the Burlington, Cedar Rapids & Northern enters the yard. Coal is used for burning. The market is local, and along the line of the above railway.

Marion. The brick and tile yard of Mr. J. Beck is situated one and one-half miles south of town. The loess is used ten feet below the surface. The brick are hand made and sun dried and have been largely used in the business blocks of Marion. Tile is also made, with the Bennett machine, and a drying shed holding 20,000 tile is included in the plant.

Lisbon and Mount Vernon. Mr. J. B. Robinson, of Mount Vernon, and Mr. Henry Goodman, of Lisbon, both use the loess, mixing the upper and lower layers. The ware, which is dried in the sun, and burned in clamp kilns, finds a market in the two towns. Mr. Robinson's brick are hand made, and Mr. Goodman uses a Quaker machine.

The tile works of Deibert and Brenneman are conveniently situated at the Mount Vernon station. A tough, pebbleless clay of loess derivation is used. The plant consists of steam engine, brick and tile machine, with a capacity of 10,000 tile per day, drying sheds and one circular down-draft kiln of the usual capacity.

Center Point. Messrs. Miller and Hart operate a tile plant at this place consisting of Chandler and Taylor machine, capacity 5,000 per day, now run by horse power, soon to be supplanted by steam, with the usual drying sheds and kiln. The tile finds market in the adjoining townships. The clay used is gray

jointed gumbo or slough clay, apparently free from pebbles of any considerable size. At the same locality Mr. Charles Johnson manufactures a hand made, sun dried brick from clay on low ground, probably derived from the looss.

Central City. Mr. A. L. Hatch makes a clean, hard brick from the upper jointed loess. The plant comprises a thirty-five horse power steam engine, a soft-mud machine, four drying sheds and a clamp kiln holding 120,000. The market is at home and in adjacent towns on the Illinois Central railroad.

Coggan. A brick and tile manufactory was recently established at this place by J. Peacock & Son, of Cedar Rapids. The plant consists of a Brewer steam crusher, an Ohio Special Frieze machine, steam engine, drying sheds, and a circular, down draft kiln, with a capacity of 40,000 three-inch tile every two weeks. The clay bank is run entire and consists of blue and yellow till. It is perhaps the stiffest clay used in the county.

LIME.

The Le Claire limestone supplies all the lime burned in the county. This formation ranks among the first lime producing rocks of the United States, furnishing a slowly slacking, slowly setting, cool lime, which displaces, wherever it is introduced, hotter limes burned from other formations. Architects and builders give it preference on account of the hardness and durability of its mortar; dolomitic lime having much the same advantages over calcareous limes, as dolomitic building stones possess over pure non-magnesian limestones. Masons and plasterers prefer it because the slowness with which it sets gives them longer time in which they may more thoroughly do their work, and also enables them to work to better advantage and therefore, on the whole, the more rapidly.

Certain physical characteristics are of advantage to the Le Claire as a lime-producing rock. It is quite free from chert, silica and argillaceous matter, containing less that one per cent of these impurities. Its porous and vesicular texture gives ready access to heat in the kiln and to water in slacking. Other counties in Iowa in which the Le Claire is found have, so far,

equal advantages with Linn, but in one respect Linn county has a special advantage which ought to stimulate the industry to greater expansion. The market for Iowa lime is largely to the west. To the east it encounters the equally good limes of Illinois and Wisconsin, made from the same or similar formations. To the west, however, it has few, if any, important local rivals. The Le Claire reaches its furthest western extension in central Iowa, in Linn county. The limes of Linn county are nearer the western market than any other Upper Silurian limes in the state. The lime rock in the county also has decayed less than is common in the Upper Silurian. Its lime is therefore heavier and gives the purchaser by the barrel an advantage which the wholesalers who buy lighter limes by weight and sell by measure understand.

VIOLA.

Mr. S. H. Gulick of Marion is the owner of two draw-kilns recently built at this place. Their capacity is 375 barrels per day. One is situated at the quarries at the edge of the village, the other at the quarry one-half mile north. Both are by the side of the Chicago, Milwaukee & Saint Paul railway tracks and lime is loaded directly from the lime houses to the cars. The fuel used is wood. The rock is of a superior quality and has already been described. The amount of stripping necessary in the Pleistocene deposits is rather large and increases as the quarries are driven back into the hill.

MOUNT VERNON.

A patent draw-kiln owned by Mr. E. M. Smith is situated above Ivanhoe bridge on the Cedar, the rock being obtained from the Palisades along the left bank of the river below Bale's branch. The long haul to the cars at Mount Vernon no doubt decreases the profit but it does not increase the price, nor does it lower the excellent reputation of the lime in the Cedar Rapids markets. This is at present the only kiln at the Palisades, but steps are being taken to open up an extensive industry at the Upper Palisades where stripping is readily disposed of in the river, and kilns can be so placed that stone can be hauled with the minimum of labor. The haul to Bertram, three miles

away, is an easy one and a track could be laid from that station without any steep grades. The rock in quantity and quality is unexcelled in the west and as the Palisades kilns will be the only ones using the Le Claire rock on the main line of the Chicago & Northwestern they would enjoy special advantages of shipment along its extensive lines. The region is forested at present, but owing to the nearness to Cedar Rapids and Mount Vernon, wood as fuel for calcination would cost more than in some other districts. The question of fuel is a vital one to lime burners, and they will suffer perhaps more directly and immediately than most other industries, by the unnecessary and rapid destruction of our forests now in progress*.

Lime has been burned in considerable quantities from other formations than the Le Claire, but, so far as known, these pot-kilns have all been abandoned and the Le Claire lime now has the entire field. The Otis beds once supplied several kilns near Cedar Rapids and one at Central City, making a "hot" non-magnesian lime. If an intermediate lime should ever be desired, the Bertram beds would furnish it of excellent quality.

SAND.

This necessary building material is readily obtained in most parts of the county from rivers or from the outcropping of the basal sands of the loess, with but little expense besides the cost of hauling.

*Since the above was written a spur of the Chicago & North-western Railway has been built from Bertram to the Upper Palisades and the erection of one of the largest lime plants in the State has been begun.

Noíò 2

GEOLOGY OF VAN BUREN COUNTY.

BY

C. H. GORDON.

GEOLOGY OF VAN BUREN COUNTY.

BY CHARLES H. GORDON.

CONTENTS.

INTRODUCTION.

Van Buren county lies on the southern border of the state, and is the second county from the east. Between it and the Mississippi river lies Lee county, while Henry borders it on the northeast, Jefferson on the north, and Davis on the west. Scotland and Clarke counties of Missouri join it on the south.

The county is an approximate square and contains 484 square miles. It is among the number which were earliest settled and was already, to some extent, occupied when visited by Owen. Since his explorations, geological work has been carried on within its limits by both Worthen[1] and White[2] though no exhaustive report on the area has heretofore been published.

PHYSIOGRAPHY.

TOPOGRAPHY.

The county is divided into two triangular areas by the Des Moines, which cuts it diagonally from northwest to southeast. In its relief it approximates that of Lee county on the east, consisting of a broad, level plain affected by a general southeast drainage. From its position, the main drainage is accomplished by the Des Moines river and its tributaries. For several miles on either side of the stream, the plain has been dissected by numerous comparatively short trenches which meet the chief water course usually at high angles. This is especially true below Kilbourne where the streams have cut deep gashes into the indurated rocks. Above the point named, the coal measure beds descend gradually to the river level and here, owing to the softer character of the rocks, erosion has effected more extensive changes in the surface. This is seen in the more general denudation and levelling which the plateau has suffered, as well as in the lessening of the angles which mark the dendritic river systems. On the northeast, the streams setting back from the Des Moines and from the Skunk have not yet completely invaded the plateau which is here broad and flat and imperfectly drained. Joined with the general plain,

[1] Worthen: Geol. Iowa, I, 219-230. 1858.

[2] White: Sec. Ann. Rep. State Geologist, 112-117. 1868.

and constituting a part of it, are the narrow divides between the tributaries of the Des Moines. These project southward nearly to the river, their summits evidently representing the remnants of the original plain surface out of which they have been carved. So also southwest of the Des Moines the plateau feature is marked, though instead of a single broad, flat prairie, like that on the north side of the river, the plain surface is here represented by a series of parallel, broad-topped divides separating the southeastward flowing streams.

General Plateau. In the southwestern part of the county, the Chicago, Burlington & Kansas City railroad has occupied the strip between the Fox and Little Fox rivers nearly to the state line. At Milton the elevation is 800 feet above tide, while a few miles east of Cantril the summit of the divide is 785 feet. East of Mount Sterling the plateau level stands at 734 feet above sea level. On the north, the highest point is at Birmingham where the elevation is 758 feet. From this point, there is a gentle slope to the east as before. Birmingham and Mount Sterling lie very nearly on the same meridian and hence their elevations indicate a southward slope of the plateau surface of twenty-four feet, or about one and one-half feet per mile. The general relief therefore corresponds to that observed in Lee county; a broad, smooth plain tilted to the southeast.

The following are the known elevations:

ALTITUDES IN VAN BUREN COUNTY.

STATION.	Above low water at Keokuk.	Above sea level at station.	AUTHORITIES.
Birmingham	291	758	Ft. Madison & D. M. R. R.
Bentonsport	122	599	Geol. Rep. 1870, vol. II.
Bonaparte	98	575	Geol. Rep. 1870, vol. II.
Boyer's	119	596	C., B. & K. C. R. R.
Cantril	293	770	C., B. & K. C. R. R.
Douds	157	634	Geol. Rep. 1870, vol. II.
Farmington	91	568	Gannett's Dictionary. C., B. & K. C. R. R.
Keosauqua	187	664	Levelled.

ALTITUDES IN VAN BUREN COUNTY—*Continued.*

STATION.	Above low water at Keokuk.	Above sea level at station.	AUTHORITIES.
River level at Keosauqua		590	
Kilbourne	147	624	Geol. Rep. 1870, vol. II.
Longview	277	754	Ft. Madison & D. M. R. R.
McVeigh	276	753	Ft. Madison & D. M. R. R.
Mount Zion	247	724	Geol. Rep. 1870, vol. II.
Milton	323	800	C., B. & K. C. R. R.
Mount Sterling	158	635	C., B. & K. C. R. R.
Selma	170	647	Geol. Rep. 1879, vol. II.
Stockport	276	753	Ft. Madison & D. M. R. R.
Willets	121	598	C., B. & K. C. R. R.

DRAINAGE.

By far the larger part of the drainage is effected by the Des Moines and its tributaries. In addition, however, two minor drainage areas appear; one at the northeast, tributary to Cedar Creek, and the other toward the southwest dependent upon Fox river.

Des Moines. The Des Moines river flows nearly due southeast, and with one exception varies little from a direct course. This exception occurs in the center of the county where the river is abruptly deflected from its course to the southwestward, but soon returns, forming a deep U-shaped loop whose axis is at right angles to the general course of the stream. The length of the loop thus formed is about five miles, while across the neck the distance is not more than two miles. To make this short distance the river takes a roundabout course of fully twelve miles. The principal tributaries to the Des Moines are Indian, Bear, Chequest and Holcomb creeks on the south, and Reed, Coates and Lick creeks on the north.

Indian creek. This creek bisects the divide between the Des Moines and Fox rivers, flowing parallel with them from its source near the western line of the county to Willett station where it turns eastward. Except in the last four miles of its course, where it invades the Saint Louis limestone, the stream

flows over a thick bed of drift. In this portion the stream has comparatively wide bottoms with more or less abrupt, but rounded slopes.

Bear creek has a comparatively steep declivity. It takes its rise on the plateau level south of Keosauqua and, soon penetrating to the rock, is bordered in the lower half of its course by more or less prominent mural escarpments. It opens into the Des Moines at a high angle just south of Bentonsport.

Chequest creek rises in Davis county and flows approximately parallel to the general course of the Des Moines, into which it empties at Pittsburg. Throughout the greater part of

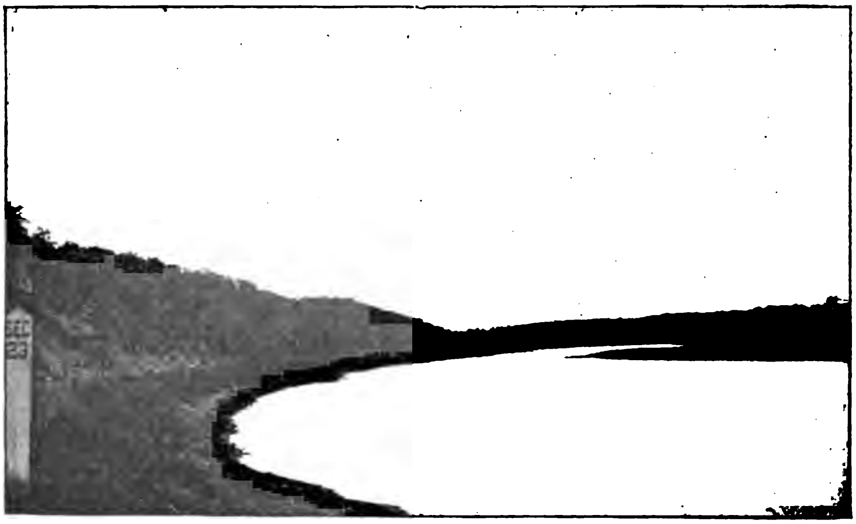


Figure 19. View looking down the Des Moines just below Bentonsport. Montrose cherts and Keokuk limestone form the escarpment at the left.

its course in Van Buren county, the stream flows over the limestone of the Saint Louis, in which it has cut a somewhat irregular channel with prominent rock escarpments.

Lick creek takes its rise in Jefferson county, flows southeastward and enters the Des Moines at Kilbourne. Throughout most of its course the channel is confined to the drift and coal measure formations, the latter of which, from lack of resisting materials, offers few exposures, and the region is marked by

rounded, hilly topography. Lick creek penetrates to the limestone, however, a short distance above Kilbourne, and from this point its course is marked by abrupt deflections and prominent rock escarpments.

Coates creek. Somewhat similar in character to Lick is Coates or Honey creek. Taking its rise in the upland plateau in numerous widely branching secondaries and flowing southward, it discharges into the Des Moines. It soon penetrates the drift and coal measure deposits, and its course thereafter is marked by more or less prominent rock acclivities carved in the Saint Louis limestone.

Reed creek is almost the counterpart of Coates, except that in its lower course it is more sinuous from deflections due to the peculiarities of the underlying rock structure.

Fox river. Next to the Des Moines, Fox river is the most important stream within the limits of the county. It takes its rise in Appanoose county, enters Van Buren about three miles north of Milton and leaves it a short distant below Mount Sterling. It flows approximately parallel to the Des Moines throughout its course and empties into the Mississippi a few miles below Alexandria, Missouri. In Van Buren county, it flows in a broad alluvial valley in which it meanders from side to side. Its channel is comparatively small and insufficient to carry the volume of water brought down during times of freshets, and overflowing, it renders a large part of the rich alluvial bottoms unfit for cultivation. Parallel with the Fox, and tributary to it, is the Little Fox in the extreme southwestern corner of the county.

STRATIGRAPHY.

General Relations of Strata.

The indurated rocks exposed in Van Buren county belong entirely to the Carboniferous formations. Exposures occur chiefly along the Des Moines and its tributaries. In the northeastern part of the county, Cedar creek and its branches also offer a limited area of outcrops.

Classification of Formations.

GROUP.	SYSTEM.	SERIES.	STAGE.	SUB-STAGE.
Cenozoic.	Pleistocene.			Teraces. Loess. Lower Till.
Paleozoic.	Carboniferous.	Upper Carboniferous. (Coal me's-ures.)	Des Moines. (Lower Coal Measures.)	
		Mississippian Lower Carboniferous.	Saint Louis.	Compact and granular limestone. Brecciated limestone. Arenaceo-magnesian beds.
			*Keokuk.	Warsaw shales and limestones. Geode shales. Keokuk limestones.
			*Burlington.	Montrose cherts.

*The Keokuk and Burlington stages as used in this report are together the equivalent of the Augusta as used in the other reports of the Survey.

Between the Saint Louis and Des Moines formations is a marked unconformity which corresponds in time to the interval represented further south by the Kaskaskia, the uppermost member of the Lower Carboniferous series in the Mississippi valley.

DESCRIPTION OF TYPICAL SECTIONS.

BENTONSPORT SECTION.

		FEET.
7.	Concealed	
6.	Limestone, magnesian; weathers brown	10
5.	Sandstone, shaly, blue; weathering to brown	5
4.	Geode bed; concealed in part	35
3.	Shales, calcareous, and limestone with chert and geodes	15
2.	Limestones, dark bluish-grey with Keokuk fossils, quarry bed	15
1.	Limestones and cherts to river level	35 to 40

Number 1 is evidently the equivalent of the chert beds at the top of the Burlington which constitutes the river bed between Montrose and Keokuk. The above rocks are also well exposed on the opposite side of the river on Bear creek.

KILBOURNE SECTION.

		FEET.	INCHES.
13.	Fire clay, red and grey	1	6
12.	Shales, arenaceous and bituminous	6	
11.	Coal		6
10.	Fire clay, grey	2	
9.	Sandstone, friable, more or less ferruginous and shaly	3	
8.	Shales, green, grey, arenaceous	6	
7.	Limestones, brecciated; upper part in places evenly stratified granular limestone	18	
6.	Limestone, magnesian, coarse, brown, vesicular	15 to 25	
5.	Concealed	10	
4.	Clay, arenaceous; blue or greenish	2	
3.	Concealed	23	
2.	Shale, calcareous, and thin beds of limestone with chert and geodes	8	
1.	Limestone, coarse, bluish-grey, with Keokuk fossils	3+	
		108	

The geodes in number 2 are not well developed, but clearly indicate their relationship to the siliceous masses in these shales at Keokuk. A well put down on the farm of Mr. H. B. Edmunson yielded the following section as given by the driller, Mr. R. G. Merrill.

EDMUNSON WELL SECTION.

(Tp. 69 N., R. IX W., sec. 26, Se. qr., Ne. ¼.)

		FEET.
10.	Clay, yellow, no sand	90
9.	Clay, blue	21
8.	Sand, no water	½
7.	Shale, dark blue	55
6.	Rotten stone, yellow, much like ochre	3
5.	Limestone, brownish	10
4.	Shales, alternating with limestone	41
3.	Limestone	41
2.	Rock, hard, dark colored with much mineral (?)	4
1.	Rock, very hard, could not penetrate it, probably Montrose cherts	
		270½

The elevation at the top of the well is about 745 feet. The shales given at number 7 may represent an unusually argillaceous development of the brecciated division not unlike that sometimes seen elsewhere. In that case numbers 5, 6, and 7 would represent the Saint Louis; 3 and 4, Keokuk, and 1 and 2 the upper part of the Burlington. The figures here given indicate a northward dip of about 140 feet in the distance of a mile and a half, between this point and Bentonsport.

A well put down on the farm of Mr. C. Davis by Mr. Merrill furnished the following record:

DAVIS WELL SECTION.

(One-quarter of a mile west of middle of Tp 68 N, R. IX W., sec. 8.)

		FEET.
16.	Clay, yellow, with some sand	35
15.	Clay, blue, joint	5
14.	Clay, yellow; in layers one and a half to three feet thick, alternating with two to six inch layers of sand and some water	16
13.	Clay, blue, very hard; with boulders	29
12.	Shale, dark brown to black	10
11.	Coal	½
10.	Clay, brown	6
9.	Clay, white, with fragments of limestone	1
8.	Limestone, white	15
7.	Limestone, bluish-grey, with some pyrite	70
6.	Shale, dark to light greenish shades	30
5.	Shale, very dark	25
4.	Limestone, cherty and arenaceous	3
3.	Limestone, grey sub-crystalline	15
2.	Limestone, darker colored, mottled pink, grey and black	23
1.	Rock, hard, brownish grey, cuts the drill	32
	Total	315

Elevation at top of well about 725 feet above tide. In this section the coal measures are represented by 9, 10, 11 and 12, the Saint Louis by 7 and 8, while the remainder is Keokuk except 1, which evidently represents the Montrose chert. This locality is nearly southwest of Bentonsport and the figures indicate a difference of about 170 feet in the elevation of the strata. The distance in direct line is about four miles, showing a southwestward dip of over forty feet per mile.

A well on the farm of Mr. C. Miller, about a mile and a half northeast of Keosauqua, gives the following:

MILLER WELL SECTION.

		FEET.
10.	Clay, gray	8
9.	Sand	32
8.	Gravel with water	2
7.	Coal	3
6.	Limestone, white	8
5.	Lime and sand	8
4.	Limestone, grey	30
3.	Sandstone, stained with iron oxide	3
2.	Sandstone, bluish grey	12
1.	Shale, blue	56
		162

This section corresponds very closely with the preceding in the thickness of the blue shale number 1. It evidently represents the Warsaw and Geode shale beds; doubtless in large part the latter.

The following section was obtained by combining sections from several localities on Indian creek opposite Farmington, no one of which gave a complete exposure of all the beds:

FARMINGTON SECTION.

		FEET.
10.	Clay, yellow, boulder	10
9.	Sandstone, incoherent, thin-bedded, brownish grey,	3
8.	Sandstone, incoherent, varying to sandy shale, ash colored "clod" below	7½
7.	Coal, impure	½
6.	Clay and sandstone, arenaceous	2
5.	Clay, residuary, containing fragments of limestone and chert, and considerable ochre	½
4.	Limestone, magnesian brown and finely vesicular	6
3.	Sandstone, blue and arenaceous shale	3
2.	Shale, blue with thin beds of sub-crystalline limestone. A bed of the limestone two feet thick in places, at the base	7 to 10
1.	Shales, calcareous. with geodes to bed of creek (base of section about five feet above river level)	2
		44½

Numbers 6 to 9 represent the Des Moines beds; 3 and 4 the Saint Louis, here nearly all removed by erosion before the deposition of the coal measure deposits, while the Warsaw, greatly

reduced in thickness, is represented by number 2, and the Geode shales by number 1. Farther up the creek the brecciated limestone of the Saint Louis stage comes in just below the coal measure deposits.

UMPHREY BROTHERS WELL SECTION AT PITTSBURG.*

(Tp. 69 N., R. 10 W., sec. 34, Nw. ¼.)

		FEET.
15.	Clay, yellow	10
14.	Sand	4
13.	Clay, yellow	5
12.	Sand	1
11.	Clay, yellow, growing harder below	4
10.	Gravel and sand firmly cemented with iron oxide	18
9.	Clay, dark, with limestone in upper part	38
8.	Shale, blue, with some limestone	30
7.	Clay, ochreous	1
6.	Clay, white	6
5.	Clay, red like umber	13
4.	Limestone, white (water)	15
3.	Limestone, grey	4
2.	Sandstone, fine, bluish grey	5
1.	Limestone, grey with pyrites (water)	37½
		191½

This well is situated on the hill south of Pittsburg, about seventy feet above the level of the river. At a point opposite the location of the well, the lower members of the Saint Louis limestone crop out in the river bank, while coal measure shales appear twenty-five to thirty feet above. The members of the section are identified with difficulty, and some doubt exists as to the reliability of the observations. The clay and shale below the gravel (No. 10) may represent the brecciated bed, or it may belong to the boulder clay of the drift, and hence indicate a filled channel. The record is inserted without attempting a correlation.

Geological Formations.

BURLINGTON.

The lowest rocks exposed within the limits of the county belong to the Burlington, the second member of the Mississippian or Lower Carboniferous series. Their exposure is confined

*Record furnished by Mr. Merrill.

to the channel of the Des Moines between Bentonsport and Bonaparte. They emerge from the bed of the river about a mile and a half above Bentonsport. At the latter place they reach a height of about forty feet above the river level, decline very gradually to Bonaparte, and then shortly disappear below the level of the stream. The only part of these beds to be seen is the chert formation at the top, which has been called the Montrose chert. They consist of beds of chert with occasional thin beds of limestone, or calcareous shale. A few feet of limestone appears at the river level on the south side, about half way between the places named, which may represent the uppermost part of the upper Burlington limestone. These beds have been penetrated by a shaft at Bonaparte and are there called the "Bonaparte Marble." The cherts break down quickly on exposure and hence offer comparatively few sections for study. Below Bentonsport, however, good exposures occur along the railroad for a mile or more.

KEOKUK.

The rocks of this member have their greatest exposure along the channel of the Des Moines from the mouth of Rock creek to the eastern limit of the county. A limited exposure also occurs at the mouth of Lick creek. They owe their exposure entirely to the erosion of the river and its tributaries, and their areal development is confined to a narrow belt along the stream.

In the vicinity of the confluence of the Des Moines with the Mississippi, this formation presents three well marked divisions. From below upwards these are the Keokuk limestone, the Geode shales, and the Warsaw shales and limestone. In Van Buren county the two lower divisions have essentially the same development as in Lee county, but the Warsaw formation is greatly reduced in thickness and evidently wedges out before reaching the northern limit of the county.

Keokuk Limestone. The general section given above represents the typical development of this bed. It makes its first appearance in the extreme southeastern part of the county on a small branch on the south side of the river. About six or

eight feet are exposed and quarried to a limited extent. The next appearance is at the mouth of Reed creek, where about ten feet of bluish grey limestone, coarse, sub-crystalline and mostly thin bedded are exposed. As the strata rise toward the west, lower beds come into view, and are seen well up in

Figure 20. Escarpment of Keokuk limestone below Bonaparte.

the bluff below Bonaparte, with nearly thirty feet of the Burlington chert beds below. The limestone has been quarried at several places here, but it contains large quantities of chert. Much of the rock is also shaly and the bedding of the better quality of rock is quite variable. At Bentonsport at one time, quarrying was carried on quite extensively. The principal quarry bed is about five or eight feet above the base of the division and perhaps represents the same ledge as that quarried at Keokuk and there termed the "white ledge." The upper layers at the quarry are thinner. The horizon between the thicker and thinner beds is marked by a series of undulations of one of the beds remarkable for their regularity. The vertical interval of the undulations does not exceed ten inches,

while the horizontal interval does not vary much from fifteen feet throughout the whole extent of the quarry. On the opposite side of the river the rocks are well exposed for some distance up Bear creek, and show essentially the same characters as elsewhere in southeastern Iowa.

Geode Shales. Above the Keokuk limestone lies a bed of bluish grey calcareous shale containing hollow siliceous masses termed geodes. The geodes vary from one inch to two feet in diameter, but are usually from six to ten inches. They are studded on the interior with crystals of calcite or quartz, or lined with chalcedony. In some places these bodies are very numerous in the beds of the streams which dissect the shales in which they occur. They are quite abundant in the vicinity of Farmington where they have been exposed by Indian creek and other small tributaries. They also occur on Bear creek and other places in the vicinity of Bentonsport. On Rock and Copperas creeks where the upper part only of the shales is exposed, the siliceous masses are irregular in shape and instead of being hollow, consist of masses of red and white, partially crystallized calcite. Their crushed form suggests that the geodic structure was here interfered with by agencies not acting elsewhere, and as there are indications of an unconformity in this locality not far above this horizon. It may be that the shales were subject to shore influences which prevented the complete development of the geodic form.

The greatest thickness of these shales known in Lee county is forty feet. At Bentonsport as shown by the section there is a covered slope of thirty-five feet with fifteen feet of the geode shales below. The concealed portion is probably in large part of the same formation; the remainder being the Warsaw. The Davis and Miller well sections, given above, agree in showing about fifty-five feet of shale at this horizon, of which about ten or fifteen feet doubtless represent the Warsaw, so that the thickness of the geode shales in Van Buren county does not vary much from forty to forty-five feet.

Warsaw Shales and Limestones. Below the mouth of the Des Moines river at Warsaw, Illinois, the upper beds of the Keokuk sub-stage have a development of about forty feet.

They thin rapidly northward however, and in Van Buren county along the Des Moines they are represented by only ten to fifteen feet of blue shales, including bands of fossiliferous limestone. Though greatly diminished in thickness they retain essentially the same characters as at the typical locality. At the mouth of Indian creek this formation is represented by seven to ten feet of blue shale with thin layers of blue sub-crystalline lime-rock. One of these beds, two feet thick, lies at the base of the division.

On Rock creek, at an old quarry (Tp. 69 N., R. IX W., sec. 16, Sw. qr.) this formation is represented by eight to ten feet of blue shales with limestones interbedded as at Farmington. The limestones here are composed in large part of the fragmentary remains of fossils many of which are identical with those of the same horizon seen at Keokuk. East of this locality, on a branch of Copperas creek, a thin ledge of limestone overlain by a few feet only of arenaceous blue shale, intervenes between the Geode bed and the magnesian limestone of the Saint Louis. The shales grade into a hard, very fine grained blue sandstone which is said to have once been used locally for scythe stones. It is thin bedded and includes broken fragments of chert and shells. A similar deposit occurs on Rock creek above the Warsaw formation. As there are commonly no means for discriminating between the shales of the Warsaw and Geode beds in well sections, there is some doubt as to what part of the fifty-five feet of shales shown in the Edmondson and Davis records belong to the Warsaw. The formation evidently does not extend much north of this area, and doubtless it wedges out entirely before reaching the northern boundary of the county.

SAINT LOUIS.

The Saint Louis limestone constitutes the uppermost division of the Mississippian or Lower Carboniferous series in Iowa, and has the greatest superficial extent of any of these members in Van Buren county. It is generally overlain by the rocks of the Des Moines stage of the Upper Carboniferous (coal measure) series, and its exposure is due chiefly to the removal of these and the overlying drift deposits by the extensive erosion of the Des

Moines river and its tributaries. The maximum thickness in Van Buren county probably does not exceed ninety feet.

In lithologial characters the rocks composing the formation show great variation. In general they present a three-fold division consisting of (1) brown, arenaceous and magnesian limestone, (2) brecciated limestone, and (3) grey, compact and granular limestone.

Arenaceo-magnesian Beds. The first of these is exposed at many places along the Des Moines and is especially well developed in the vicinity of Kilbourn and in the bluffs below Keosauqua. It consists of fine-grained or vesicular magnesian limestone in

Figure 21. Old quarry at the mouth of Rock Creek. Arenaceo-magnesian beds overlain by brecciated limestone.

rather heavy ledges, which grade horizontally into a more or less clearly marked arenaceous rock characterized in places as a sandstone. A large percentage of the rock, however, is made

up of calcareous matter, and hence it is more properly designated as an arenaceous limestone. It is well developed on Price and Bear creeks where it furnishes a very good quality of stone for building purposes, and has been quarried quite extensively for plates and sills. This bed represents that quarried at Belfast and Keokuk. It constitutes the upper member of the Warsaw as originally defined. The arenaceous character is confined generally to the lower part of the beds, but on Bear creek as well as elsewhere, sand forms the larger part of the formation, The magnesian limestone constitutes the most generally recognized phase of the division in the county. When first removed from the bed, the rock is of a blue or drab color, but it soon changes to a rusty brown by the oxidation of the iron which it contains. In general, therefore, the exposures of both the arenaceous and magnesian ledges are characterized by a rusty brown color. The magnesian rock occurs in thick, gently undulating beds, and is distinguished by a more or less concretionary structure by reason of which it was at first termed the Lower Concretionary limestone by Owen. In places these beds are interrupted by the brecciated phase which in these instances is in direct continuity with that of the overlying bed. The thickness of the arenaceo-magnesian beds varies from ten to twenty-five feet.

Brecciated Limestone is a widely recognized phase of the formation in Iowa. The bed is made up generally of compact and granular, grey limestones, in sharp angular fragments of various sizes cemented together by similar calcareous material. In many cases the fragments show more or less rounding as though they had been subjected to the wearing action of water. In the thicker portions of the beds, the spaces between the fragments are filled with greenish clay which sometimes contains fossils. There is usually a coarse stratification observable. In some cases the disturbing agencies have but very slightly affected the orderly arrangement of the formation. Elsewhere, however, the brecciated character is marked, as for instance near the mouth of Reed creek, where it affects the whole of an exposure seventy-five to eighty feet in height. The lower portion represents the arenaceo-magnesian bed and

is composed of large fragments of this limestone with clay filling the interstices, while the upper part is made up of the compact and granular limestone more completely cemented. In a few instances the brecciated character has been observed to fail altogether and the lower division is succeeded by compact grey limestone similar to that of which the brecciated bed in its general extent is composed, and which is indistinguishable from the limestone constituting the upper division. In the vicinity of Keosauqua, the upper portion of the bed contains more or less arenaceous material. This is well marked on the south side of the Des Moines above the town, where a brown sandstone ten to twenty feet thick replaces nearly the whole brecciated division and is overlain by the limestone described farther on. Two or three miles below, the sandstone varies from five to twenty-five feet in thickness and rests upon the brecciated bed, while it is overlain by the compact limestones as shown in the bluffs opposite Keosauqua. This sandstone was regarded by White* as the equivalent of that above the Warsaw shales at Keokuk and the town of Warsaw.

The sandstone at Keosauqua is decidedly calcareous in places, and sometimes includes irregular ledges and fragments of limestone. It is there seen to be closely related to the brecciated division and evidently constitutes a phasal development of that formation. Outside of the ox-bow area it has been recognized at two localities only; one on Coates creek and the other in Lee county on a branch of East Sugar creek. The thickness of the brecciated division varies from nothing to seventy-five feet. In general however, it may be said to be from ten to twenty feet thick.

Compact and Granular Limestone. Overlying the brecciated limestone in places, and the Keosauqua sandstone where that formation occurs, is a compact, fine-grained, grey limestone characterized by having a conchoidal fracture, concretions, and a considerable number of fossils, the most prominent of which are *Spifer littoni* Swallow, and *Rhynchonella ottumwa* White. In some places the compact limestone is replaced by a thin bedded limerock with a marked granular structure often cross-bedded

*Geology of Iowa, vol. I, p. 318. 1870.

and showing well developed ripple marks upon the surface. The limestone of this upper division is well developed along Indian creek where the compact variety is quarried quite extensively. It is also quarried at Keosauqua on both sides of the river. In some localities it is absent, allowing the brecciated beds to constitute the surface rock. This is prevailingly the case in Lee county. While in general its absence may be attributed to erosion, it seems probable that it may often be accounted for by non-deposition, and toward the north doubtless this is generally the case. The thickness of the bed does not exceed fifteen feet.

DESCRIPTION OF SECTIONS.

Opposite Farmington, just above the railroad bridge, twenty feet of arenaceous shales, with some coal, appear about thirty-five feet above the level of the river. A few hundred yards above this the bluff shows about thirty feet of limestone more or less brecciated and disturbed. The limestone replaces the sandstone and shales, showing that the latter were deposited in a depression in the surface of the limestone. The accompanying figure illustrates these relations.

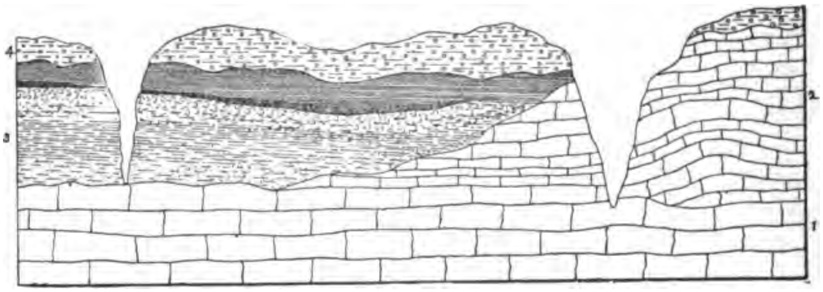


Figure 22. Section at Farminton showing coal measure deposits resting in depression in Saint Louis limestone. 1. Arenaceo-Magnesian beds. 2. Brecciated limestone. 3. Coal measure, sandstone and shales with seams of coal. 4. Surface clay.

On Indian creek a short distance above its mouth, the arenaceo-magnesian member is represented by three feet of sandstone, overlain by a like thickness of magnesian limestone, and resting on this are coal measure deposits. A short distance above this locality, the brecciated limestone appears, intervening between the magnesian limestone and a sandstone which

may represent the basal member of the coal measures, though it may be the equivalent of the Keosauqua sandstone. About a mile west of Boyer station, the compact, white limestone has been quarried quite extensively, fifteen feet of the limestone being exposed above the creek bed. The lower three feet is somewhat thinly bedded and granular, the remainder is a light grey compact limestone with some nodular chert. The rock is very hard, breaks with conchoidal fractures, and weathers white. In the clay seams separating the beds a number of fossils are found, the most common being *Spirifer littoni* Swallow and *Rhynchonella ottumwa* White.

A quarter of a mile east of this, at an old lime kiln, a rock evidently representing the lower part of the above is cross-bedded and granular in structure. On Reed creek, three-fourths of a mile above its mouth, the eastern bluff shows a rock face seventy-five feet high, all of which is more or less brecciated. The lower two-thirds is composed of large, irregular masses of brownish limestone, with green clay filling the interstices, and the whole very irregularly and coarsely stratified. The upper part of the escarpment is composed of white limestone breccia and is more regularly stratified. The limestone in the lower part has evidently been derived from the underlying magnesian limestone, while the upper is as manifestly related to the white limestone. Between this point and the mouth of the creek, on the west side, the lower portion of this section is replaced by the arenaceo-magnesian beds as follows:

		FEET.
3.	Limestone, brecciated	5
2.	Limestone, magnesian, blue; weathering brown; lower stratum disturbed along the middle where it is made up largely of clay with included siliceous fragments, more or less water worn	20
1.	Sandstone, blue, calcereous	4
		29

In the north bluff of the Des Moines, above the mouth of the same creek, the magnesian limestone has been quarried. It is here overlain by eight to ten feet of brecciated limestone. Near by, the latter is seen to grade upward into a cross-bedded

granular variety. On Bear creek, the blue sandstone has been extensively quarried (Tp. 68 N., R. IX W., sec. 11, Nw. qr.). It is here nearly twenty feet thick and is composed of massive sand beds separated by a considerable thickness of arenaceous shales. Farther up the creek it is more regularly bedded and grades into blue and brown magnesian limestone. At the mouth of Rock creek the following section is shown:

ROCK CREEK SECTION A.

		FEET.
6.	Concealed	5
5.	Limestone, compact, grey; breaking with conchoidal fracture; contains abundant *Spirifer littoni* Swallow and *Rhynchonella ottumwa*, White	6
4.	Sandstone, brown quartzose	4
3.	Limestone, brecciated, well cemented	20
2.	Limestone, hard, blue; weathering brown; heavily bedded and concretionary	14
1.	Concealed to river level	35
		84

Number 2 has been quite extensively quarried here for the old river improvements. About one-half mile north-west another old quarry shows some of the underlying beds.

ROCK CREEK SECTION B.

		FEET.
4.	Concealed	5
3.	Limestone, magnesian, concretionary, in heavy ledges; lower bed irregular	23
2.	Shale, sandy, blue and ash colored; inclosing fragments of chert and buff colored limestone more or less confusedly interstratified; lower portion partially decomposed limestone	6
1.	Shale, blue; interbedded with coarse sub-crystalline limestone, composed in large part of fossil fragments	8 to 10
		44

The lower bed here belongs to the Warsaw and the presence of concretions in the bed of the creek indicates that the Geode shales lie not far below.

About one mile southwest of the locality of the first section, the sandstone (No. 4), has a local development of nearly twenty-five feet. Two and one-half miles below Keosauqua on the

south side of the river, a high escarpment shows a similar section. Here the lower beds are arenaceous, grading horizontally into more or less pure magnesian limestone. Opposite Keosauqua the same sandstone is very irregularly stratified. An exposure at the south end of the bridge shows imperfectly consolidated calcareous sandstone including some limestone. In the ravine south of the bridge is the Manning quarry which has been opened in the grey, compact limestone overlying the sandstone. These beds have a thickness here of about twelve feet. The thin clay seams separating the beds are filled with fossils. These beds are equivalent to those quarried on Indian creek. They are also quarried on the north side of the river below the city. One-half mile southwest, on Thatcher creek, the sandstone is seen to include irregular beds of siliceous limestone. Another exposure in this vicinity shows a brecciation of the beds, evidently of later date, as it seemingly occupies a channel-like depression cutting through the sandstone to the limestone below. Above the mouth of the creek, the sandstone is fifteen to twenty feet thick and constitutes a rather bold escarpment along the river for a distance of more than two miles. It is overlain by the grey, compact limestone noted in the quarry at Keosauqua.

The Saint Louis limestone is well exposed all along Chequest creek from the middle of Chequest township to Pittsburg. The lower portion of the magnesian limestone grades locally into sandstone. This sandstone is taken out at the Price quarry (Tp. 69 N., R. X W., sec. 20, Sw. qr.). The rock here consists of a rather bluish gritstone which becomes brown and hard on exposure, thus constituting a good material for heavy masonry. The beds are cross-stratified and in places are too irregular for quarrying. Following down the branch they are seen to grade more or less into the magnesian beds along Chequest creek.

CHEQUEST SECTION.

(At mouth of Price creek.)

		FEET.
3.	Limestone, grey, compact; upper part somewhat granular, several ledges furnishing good quarry rock; a layer of dark colored, compact limestone near the base known as Chequest marble	20
2.	Limestone, blue or brown, arenaceous; the equivalent of the sandstone at the Price quarry,	8 to 10
1.	Limestone, graded downward into blue arenaceous shales	2

In this section the brecciated bed is absent. The brecciated character, however, is well developed at various other localities along Chequest creek. Its place here is evidently represented by the lower part of number 3.

About one and one-half miles southeast of Kilbourne the bluff gives the following:

		FEET.
7.	Limestone, white or grey, granular, replaced horizontally by a thickening of number 6	10
6.	Limestone, brecciated	1 to 10
5.	Limestone, magnesian, buff and brown in three or four heavy ledges	10
4.	Limestone, magnesian, fine-grained, soft; breaks down readily on exposure	2
3.	Limestone, magnesian, very siliceous and concretionary; lower ledge disturbed and replaced in part by clay containing siliceous fragments apparently water-worn	3
2.	Shale, blue, arenaceous; with more or less calcareous and magnesian material; imperfectly bedded	6
1.	Concealed to river level	20

On Lick creek both the magnesian and the brecciated limestones are well developed; the former showing marked indications of cross-bedding. These beds are also well exposed on Coates or Honey creek.

DES MOINES STAGE OR LOWER COAL MEASURES.

These deposits cover the larger part of the county, though over considerable areas occurring only as a thin veneer filling the irregularities in the surface of the underlying limestones. The depressions sometimes take the form of trough-like basins

extending north and south and are evidently due to conditions of antecedent drainage. One of the basins is in the southeastern part of the county, apparently trending northeast and southwest, and dissected at Farmington by the Des Moines river. Coal has been mined to a considerable extent on the north side of the stream. Its presence on the south side is shown by outcroppings along Indian creek and by mining which has been carried on at the Height bank (Tp. 67 N., R. VIII W., sec. 3, Se. qr). An attempt was made to mine the coal in the bluff opposite Farmington but it was unsuccessful. On the north side considerable coal has been mined (Tp. 68 N., R. VIII W., sec 36, Nw. qr.) but these workings are not now operated. A mine in the southeast quarter of section twenty-six of the same township and range is still being run on a small scale. The coal here occurs in small detached areas varying from ten to twenty-five acres in extent. It fills basin-like depressions in the underlying limestones. Four of these are known on the north side at Farmington and are found to be approximately parallel with the course of the river.

Each coal bed is usually underlain by fire clay and sandstone, but this sandstone occasionally fails, and then it rests directly upon the limestone. In some cases the fire clay and sandstone occur at the center, but wedge out at the edge of the basin. The following represents the succession as shown by drill records in a coal area.

FARMINGTON COAL SECTION.

		FEET.	INCHES.
18.	Clay, reddish, yellow	60	
17.	Clay, blue	20	
16.	Shale, black 6 to	10	
15.	Sandstone, coarse grey	1	8
14.	Coal	1	2
13.	Sandstone		8
12.	Coal	1	
11.	Fire clay and shale, bluish	5	
10.	Shale, blue	15	
9.	Shale	2	6
8.	Coal		6
7.	Sandstone		3
6.	Coal		1
5.	Sandstone	1	8

		FEET.	INCHES.
4.	Coal	4 to 5	
3.	Fire clay	0 to 3	
2.	Sandstone	0 to 6	
1.	Limestone (Saint Louis)	1	
		135	6

Number 4 furnishes the only workable bed of coal of this area. As it is not continuous, however, no correlation can be made with other districts.

North of Bonaparte another north and south depression gives rise to several basins of coal along Coates creek. These have not been fully developed and some of them may prove of sufficient extent for profitable working.

Northwest of Bentonsport, the coal measures rest upon the declining surface of the lower beds. On the Shepherd farm coal is obtained by stripping near the road opposite the farm residence. The Edmunson well is situated about a mile and a quarter southeast of this on much higher ground, but shows no coal measures, so that the coal bed probably belongs to a small outlier.

Coal occurs north of this and is said to have been taken out for local use (Tp. 69 N., R. XIX W., sec. 23, Ne. qr). A depression in the limestone on Rock creek, three-fourths of a mile above its mouth, is filled with the bituminous shales of the coal measures. There are indications of coal in a ravine about half a mile west of this, and again farther up the stream. The Miller well section shows three feet of coal at a depth of forty-two feet from the surface. These occurrences evidently all belong to the same depression extending from the northeast toward the southwest.

On the south side of the river at Keosauqua, coal has been mined in the bluff below the bridge, and also along a ravine near by opening into the main valley. On Ely creek coal-bearing shales appear considerably below the level of the uplands.

Southeast of Keosauqua the coal measures crop out at several places. The Davis well record shows sixteen feet of shales including a three inch seam of coal, underlain by one foot of clay. An exposure about two miles east of this on Bear creek

(sec. 10), exhibits clays and shales with two thin seams of coal resting upon the Saint Louis limestone. About a mile north of the latter place considerable coal has been mined on the Boyer farm (Tp. 68 N., R. IX W., sec. 3).

In the northwestern part of the county the coal measure rocks have a much greater development, and include workable seams of coal at several localities. Several mines are operated at Douds station at a horizon considerably above that of the coal in the eastern part of the county. The following section was made at the Findley mine about one mile northeast of the station near Business Corners.

BUSINESS CORNERS SECTION.

		FEET.	INCHES.
12.	Concealed	20	
11.	Shale, blue, argillaceous	10	
10.	Coal		6
9.	Shale, arenaceous; filled with plant remains		10
8.	Coal		6
7.	Shale, becoming more argillaceous below	3	
6.	Coal		6
5.	Sandstone, filled with plant remains	1	
4.	Fire clay 1 to	2	
3.	Shale, black, fissile above, more compact below filled with ironstone concretions; the basal portion contains lenticular masses of black calcareous rock 4 to	5	
2.	Coal, sometimes partially cut out by the nodular masses above 3 to	4	
1.	Fire clay	2	
		49	4

In sinking the air shaft for the Carson mine not far from where the above section was made no coal was found. A boring was then put down to the limestone, a distance of sixty feet, all of which was found to be composed of clays and shales.

About a mile east of the station, in a small ravine, an eighteen inch seam of coal is seen above eight to ten feet of light colored shales and sandstone which in turn rest upon the Saint Louis brecciated limestone. This evidently occupies the same horizon as the beds worked in the eastern part of the county. The following is a section at the Ratcliff shaft. (Tp. 70 N., R. XI W., sec. 23, Nw. qr.)

RATCLIFF SHAFT SECTION.

		FEET.	INCHES.
13.	Clay	10 to 11	
12.	Shale, black, bituminous	11	
11.	Coal		6
10.	Fire clay	2	
9.	Shale	3 to 4	
8.	Limerock, black	1	
7.	Coal	1	6
6.	Fire clay	2	
5.	Shale, grey with limestone masses	4 to 6	
4.	Coal	3 to 4	6
3.	Fire clay	4	
2.	Concealed	8	
1.	Shale, blue; in well which starts about twelve feet below coal	22	

The coal on the Hinkle land (Tp. 70 N., R. III W., sec. 10, Sw. qr.), evidently occupies about the same horizon as the Doud coal. In the northeastern quarter of the same section a three to four foot bed of coal occurs on the farm of A. Overturff, not far below the plain level.

OVERTURFF SECTION.

		FEET.	INCHES.
12.	Shale, black	8	
11.	Coal	3	
10.	Clay seams		2
9.	Coal		8
8.	Fire clay	4	
7.	Concealed	30	
6.	Shale, black bituminous	8	
5.	Limerock, hard black, variable in thickness		2 to 10
4.	Shale, black fissile	2	
3.	Shale, black, argillaceous	2	
2.	Coal	1	6
1.	Fire clay	1	

The branch on which this exposure occurs is tributary to that intersecting the Hinkle area. In the absence of any indication of southward dip therefore, it seems safe to assume that the coal at the Overturff place represents a higher horizon than any yet considered.

While the coal measure rocks are known to occur on the south side of the river, they have, as yet, furnished very little workable coal. Near Selma, however, a bed has been worked for many years (Tp. 70 N., R. XI W., sec. 17, Sw. qr.). Recently on the Leifer land a test for coal has been made below that now worked, the section showing:

LEIFER SECTION.

		FEET.
7.	Coal (operated)	3
6.	Fire clay	4 to 6
5.	Shale, dark	4 to 6
4.	Shale, black, hard	40
3.	Shale, blue, hard	23
2.	Shale, white, gritty	1
1.	Limestone, hard, could not penetrate with drill	

The drilling began in number 4; number 1 is evidently the Saint Louis limestone.

In boring for coal at Birmingham the following record was obtained, the location being at the depot of the Fort Madison & Des Moines railway; elevation 758 feet above tide.

		FEET.	INCHES.
14.	Soil, black	2	
13.	Clay, yellow	*	
12.	Sand, fine, white		4
11.	Sandstone, grey	13	8
10.	Coal	1	2
9.	Shale, black	4	10
8.	Shale, red, sandy	10	
7.	Shale, black	4	
6.	Coal, impure	1	
5.	Shale, grey	1	2
4.	Limerock, black, bituminous		10
3.	Coal, impure	5	6
2.	Shale	10	
1.	Limestone, white	12	
		106	6

The seams encountered were not regarded as workable here. The Smith drift has recently been opened. The location of the mine is about eighty feet below the Birmingham depot. The

*Thickness of yellow clay doubtful. Original record gave 4 feet; a manifest error.

erosion of the streams has exposed coal measure strata at numerous places between Birmingham and Mount Zion. Outcrops in this region show a considerable development of sandstone, probably the equivalent of members of the Birmingham section. On a branch of Lick creek (Tp. 70 N., R. IX W., sec. 30.) near the school house the following rocks are exposed:

SCHOOL HOUSE SECTION.

		FEET.
5.	Sandstone, soft, micaceous, shaly; cross-bedded, becoming more or less massive in places	10
4.	Sandstone, ferruginous, nodular, disturbed bed; pieces of bituminous shale, coal, etc	1
3.	Coal, impure	1
2.	Fire clay 3 to	4
1.	Concealed to bed of creek	8
		24

The coal here is about 110 feet below the Birmingham depot. In a branch on the Hartman farm in the southern half of section 32, (same range and township) is a section which belongs to a horizon immediately below the preceding:

HARTMAN SECTION.

		FEET.
6.	Sandstone, brown, shaly	3½
5.	Shale, sandy, grey, fissile, filled with iron concretions	4
4.	Iron ore, nodular band 2 to	4
3.	Shale, blue, argillaceous; becoming black below; contains lenticular masses of black limerock above	6
2.	Coal, irregular in thickness (average)	1
1.	Fire clay	2
		30½

The iron ore is closely associated with the limerock and is probably a replacement of the latter. The sandstone thins toward the west to a single ledge but thickens rapidly toward the southeast and is ten to fifteen feet thick a quarter of a mile away. If the sandstone here represents that seen in the school house section, which would seem to be the case, it indicates a northward dip to the beds of about seventy-five feet in a distance of a mile and a half. This dip is clearly indicated by the appearance of the beds where exposed.

On Rock creek about a mile east of Mount Zion a good exposure occurs on the Baker farm (Tp. 69 N., R. IX W., sec. 9, Sw. qr).

BAKER SECTION.

		FEET.	INCHES.
9.	Clay, alluvial	5	
8.	Coal, partially disintegrated		8
7.	Fire clay	3	6
6.	Shale, black, bituminous	10	
5.	Limerock, nearly black, bituminous; in a single ledge varying in thickness from..2 to	10	
4.	Shale, bituminous, with some coal......1 to	6	
3.	Fire clay	3	
2.	Coal		3 to 8
1.	Shale, drab colored	1	

Shales and sandstones with indications of thin seams of coal occur at a higher level in the hillside to the east. Northeast of Birmingham a branch leading into Cedar creek has cut through the full thickness of the coal measure deposits. Several coal seams are exposed but none are of workable thickness. The section very closely approximates that of the drill record at the depot.

The coal measures become thin eastward and are cut through in the northeastern part of the county by Cedar creek and its tributaries. They include some workable beds of coal which are referred to elsewhere.

Several well records in the northeastern part of Harrisburg township show no evidence of coal-bearing strata. In the southwestern part of the county the indurated strata are effectually concealed by a heavy covering of drift which the deepest wells yet made have failed to penetrate.

EXPLANATION OF PLATE.

PLATE VI.

Figure 1 represents a profile section from Farmington to Selma along the Des Moines river (*A–B* geological map). In this, number 1 is the Burlington, 2 the Keokuk, 3 the Saint Louis, 4 the Des Moines (coal measure), and 5 the drift.

Figure 2 is a section from Birmingham to Cantril through Keosaqua (*C–D* geological map). The numbers in this section refer

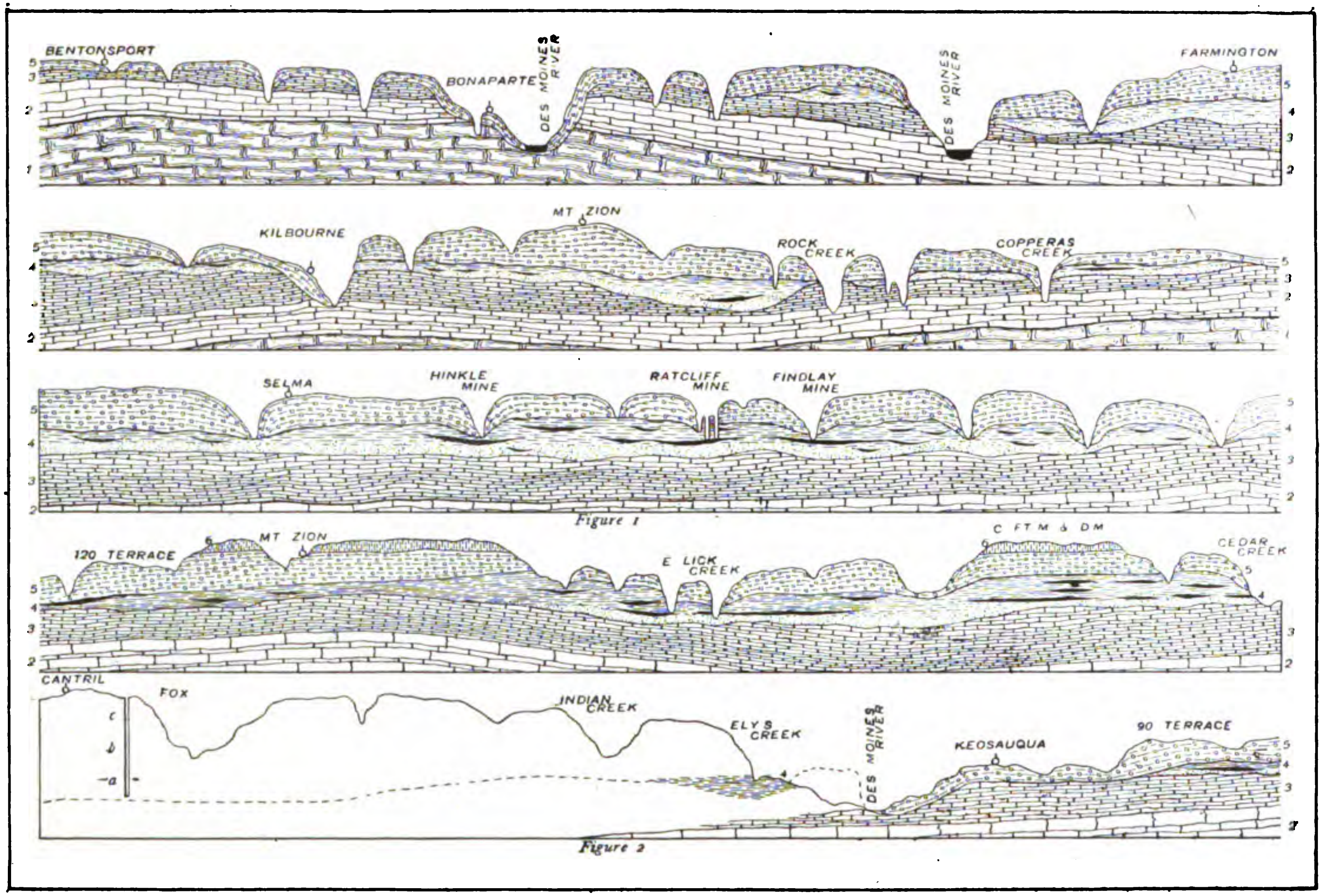
to the same formations as in figure 1; in addition, number 6 refers to the loess. In the well at Cantril *a* represents sand and gravel; *b*, blue clay; *c*, yellow clay.

PLEISTOCENE.

The Pleistocene deposits comprise the incoherent materials consisting of clays, sands, gravels and boulders which rest upon the indurated rocks. They originally covered the whole surface, building it up to a nearly uniform level, but they have since suffered much from erosion. Of later age are the alluvial deposits occurring along the valleys. These deposits may be classified as glacial, drift-loess and alluvium.

GLACIAL DEPOSITS.

The glacial deposits consist of two well marked divisions of boulder clays, each including more or less sand and gravel, a lower blue clay and an overlying yellow clay. No well defined boundary separates the two phases. They appear to grade gradually into each other, though the transition usually takes place within the space of a few feet. The opportunities for observations as to their relations, however, are few owing to concealment. At one point in the neighboring county of Lee, the blue clay was seen to terminate abruptly while the overlying deposit consisted of sand more or less cemented by iron oxide. As yet no satisfactory basis has been found for the separation of the two deposits, if indeed they do not belong to the same general formation. The most obvious distinction between the two is their color, and this is so patent as to be remarked by every well digger. Whether the characteristics of the yellow clay have a genetic significance or are due chiefly to oxidation and leaching is still an open question. The great thickness of this portion of the drift in places might be held to favor its separation from the blue clay. provided it is found to be supported by juncture phenomena, In the absence of such evidence however, it may be adduced as an indication of the vast period of time during which the deposits have been exposed to oxidizing agencies. The rate at which oxidation takes place downward, and the time which has



GEOLOGICAL CROSS-SECTIONS IN VAN BUREN COUNTY.

Scale { Vert. 200 feet.
Hor. 1 mile.

elapsed since the withdrawal of the ice from this region are as yet wholly matters of conjecture. The separation of the clays is here made only as a matter of convenience in description, and is not intended in any sense as an expression of opinion as to their genetic relationship.

Blue Clay. The lower clay is dark blue, compact and hard. It is filled with crystalline pebbles and small boulders frequently worn and striated. Among these greenstone and quartzites are common. Occasionally larger boulders of quartz-porphyry and granite may be observed. These are most abundant along the valley of the Des Moines, having been uncovered by the river in the process of erosion. No distinct boulder trains or morainic deposits have been observed in the county. The blue clays include lenticular beds of sand or gravel which are usually relied upon for the water supply in the wells of the region. The thickness of the deposit in the northern and eastern part of the county, as shown by well records, varies from nothing to about fifty feet. It is much thicker in the southeastern part, as indicated in the Holland well north of Milton, and also in the Manning well near Cantril. In the bluffs of Fox river (Tp. 68 N., R. X W., sec. 31, Ne. qr.), there is a thickness of about seventy-five feet of blue clay overlain by twenty feet of yellow clay. The blue clay here contains an abundance of pebbles, many of them striated, pieces of coal, and iron nodules. Large boulders are rare.

Yellow Clay. The yellow clay rests upon the blue clay, and usually conceals it from view. In color it varies from buff to reddish yellow. It is arenaceous in places, sometimes grading into sand. These local sand areas within the more general clay formation often furnish supplies of water, as in the case of the blue clays below. Moreover this division evidently contains a much greater proportion of calcareous matter than does the blue clay. Pebbles are common, usually small and worn. Striated boulders are present, though less abundant than in the blue clays below.

The clay is cut irregularly by more or less vertical cracks which have become filled with lime by infiltration. In addition to this, the clay is more or less filled with concretionary

nodules of lime from one half to one inch in diameter. These resemble loess-kindchen. In some cases they are seen to be solid with a sand grain at the center. Often the calcareous concretions appear very abundant. No distinct evidences of stratification have been observed though such have been noted in this deposit in adjoining counties.

At numerous places the surface of the yellow clay is much oxidized and often has a well marked band of pebbles separating it from the loess above. When wet, the clay becomes soft and tenaceous, and in excavations gives much trouble from its tendency to creep. Usually the yellow clays vary from twenty-five to fifty feet in thickness.

The so-called "buffalo-licks" found in different parts of the county evidently represent localities in which these yellow clays contain a greater proportion than usual of calcareous matter and probably also a limited amount of salt, though no indications of this were detected.

LOESS.

The loess consists of fine ash-colored silt-like deposits resting upon the yellow clay. It rarely contains pebbles though occasionally small crystalline masses are observed. In well developed exposures, the lower portion consists of a dark, friable silt, while the upper part is much lighter colored and somewhat marly in appearance. West of Mount Zion a railroad cut shows the following arrangement:

		FEET.
5.	Soil	1½
4.	Loess, fine whitish silt	1½
3.	Loess, yellowish	4
2.	Loess, dark friable silt-like clay, containing loess-kindchen	4
1.	Clay, yellow with sheets and concretions of lime	30
		41

In thickness this formation does not exceed ten feet, the maximum being found on the uplands adjacent to the Des Moines river. It diminishes in thickness away from the river, and over the larger part of the county it constitutes only a thin veneer two or three feet in thickness. Much of it has been

removed by denudation along the Des Moines, the remainder forming a thin capping to the divides which still represent portions of the original plain level.

In well records the loess deposits are not differentiated from the yellow clays, and their absence in such sections therefore is not to be construed as an indication of non-development. The Holland well (Tp. 68 N., R. XI W., sec. 8, Sw. qr.), about two miles north of Milton gives the following arrangement:

		FEET.
4.	Clay, yellow	23
3.	Clay, dark blue, with some sand about sixty-five feet from top	181
2.	Rock, rather soft	1½
1.	Clay and sand with some gravel (water-bearing)	12
		217½

Water rose in the pipe 165 feet from the bottom. This well is located in the valley of Fox river, forty or fifty feet above the bottoms. A well on the Hargrave farm, one-fourth of a mile away and probably twenty-five feet below this, derives its supply of water from a sand bed under about twenty feet of yellow clay. This sand bed is evidently near the base of the yellow clay division. It is absent at Holland's, but apparently crops out near the level of the stream below. The Edmonson well, situated one-half mile north of Holland's, is 204 feet deep with a corresponding record. A well put down on the Manning farm (Tp. 68 N., R. X W., sec. 31, Nw. qr.), near Cantril shows:

		FEET.
3.	Clay, yellow	50
2.	Clay, blue, with boulders	60
1.	Sand and gravel with water	41
		151

Northeast of Bonaparte several wells have been drilled to rock, giving the following records.

CRESSWELL WELL SECTION.

(Tp. 69 N., R. VIII W., sec. 11, Sw. qr.)

		FEET.
3.	Clay, yellow	92
2.	Limestone, yellowish to white	6
1.	Limestone, white, in thin strata (water)	34
		132

This well is located on the prairie level and is noticeable in showing the absence of the blue clay. However, it is probable that a part of number 3 is referable to this division.

Nine miles northeast of Bonaparte is the Endersby well (Tp. 69 N., R. VIII W., sec. 12, Se. qr.).

		FEET.
3.	Clay, yellow	35 to 50
2.	Clay, blue, white below; contains gravel bed about thirty feet above the base	60 to 70
1.	Limestone, hard	1
		121

A well on the Percival farm one-half mile west of the preceding is 104 feet deep and shows a similar record.

ALLUVIAL DEPOSITS.

Alluvial deposits are well developed along all the larger streams and in the lower portions of the smaller tributaries. They occupy the comparatively wide bottom lands of Fox river and Indian creek, thinning out toward the top of the bluff on either side. Along the Des Moines, considerable areas are underlain by this formation, as at Farmington, Keosauqua and above Kilbourne. The extent of the deposits along the Des Moines, however, compared with the size of the stream, is much less than along Fox river. They are made up of dark colored silts, fine clays, sands and gravels. Along Fox river the clays and silts predominate.

The bottom lands are usually underlain by tough clays constituting an intractable soil prone to bake in dry, and drown in wet weather. These clay soils of the bottom lands are locally called "gumbo-soils."

Along the Des Moines river the most marked character of the deposits are the sand terraces marking the position of the river during various stages of its history. These are especially well developed in the Keosauqua "ox-bow." In this area eight well marked terraces have been determined, reaching up to an elevation of 145 feet above the level of the river. The remains of these terraces are in part represented upon the accompanying topographical map of the area.

HISTORY OF THE DES MOINES.

The present channel of the Des Moines river evidently dates from the glacial epoch. Where the river encounters the limestones of the Mississippian or Lower Carboniferous series, the channel is comparatively narrow with more or less precipitous rock escarpments.

West of Kilbourne, the soft coal measure rocks descend, passing below the river level near the west line of the county. Here the valley is wider and the slopes more gentle. In the vicinity of Farmington also, a similar condition prevails, though here in part attributable to depressions in the surface of the limestones. This valley therefore well illustrates the principal "that mature and old forms are more rapidly developed on soft than hard rocks." As a whole the valley shows the topographical characteristics of youth.

Figure 23. View at Keosauqua looking north from the bluff on the south side of the river.

At the middle of the county, the river forms a loop not unlike an ox-bow in shape. Between the upper points of the loop, the surface is very nearly on a level with the general plain to the northeast, of which plain it forms a part, (758 feet above

sea level). Along the line of the railroad, this has been reduced slightly by the backward erosion of the branches. It is evident that the Des Moines river flowed over this point, but was deflected southward somewhat at the very beginning. This course was probably determined by a slight depression below the general plain level, possibly due to irregularities in the rock surface or to glacial drainage. As erosion went on, its efforts were directed toward straightening its course by the corrasion of its left bank at the Kilbourne bend. The effect of this, however, was to cause still greater deflection southward which was increased when the hard limestones below were encountered. As the loop gradually extended itself southward, the stream encountered similar resisting rock walls, but of somewhat softer constitution, so that corrasion took place here more rapidly than before. For a time the corrasion was fairly uniform, giving the loop a regular outline. After reaching the ninety foot terrace level, however; the soft Keosauqua sandstone had been penetrated toward the east. By the descent of the strata to the southwest this sandstone remained about at the river level, so that while corrasion was taking place quite rapidly in the soft sandstone toward the southwest the hard limestone eastward offered a much more effectual resistance, giving rise to the northward bend below Keosauqua, instead of a uniform curve which would result if the rocks were of uniform hardness.

Terraces. The highest terrace is about 140 feet above low water at Keosauqua. From this point the terraces descend quite uniformly. The most marked are the following:

145 feet	120 feet	90 feet
75 feet	50 feet	25 feet
15 feet	and	10 feet

These terraces are marked upon the accompanying topographic map of the Keosauqua region. (Plate vii.)

Geological Structure.

DEFORMATIONS.

Bentonsport Anticlinal. In general, the strata have a southerly slope of about four or five feet to the mile. Corrugations

A

POGRAPHIC MAP

OF THE

SAUQUA OXBOW

BY

HARLES H. GORDON.

LEGEND

GHWAYS

RRACES

ALE : 1 INCH = 1 MILE.

NTOUR INTERVAL 20 FEET.

A.Hoen & Co. Lith. Baltimore.

of a minor character, however, interrupt the general inclination. The most pronounced of these beds is the Bentonsport arch and anticlinal, having its crest at the place from which it takes its name. Its strike is about N. 63° W., pitching quite abruptly toward the west but gradually toward the east, reaching the Mississippi near Nauvoo at which point it is scarcely perceptible, (figure 1, plate vi.)

At Bentonsport forty feet of the Burlington cherts are exposed above the river, indicating a rise of nearly 140 feet from Farmington to this place. A descent toward the north appears to pass into a trough-like depression between Mount Zion and Birmingham. This is illustrated in the accompanying profile section from Birmingham to Cantril (figure 2, plate vi). The uplift giving rise to the Bentonsport arch evidently occurred before the deposition of the coal measures. This is indicated by the way these deposits lie against it on the north, as shown by the arenaceous character and relations of the beds north of Mount Zion. Moreover the character of the Saint Louis formation in this vicinity favors the belief that the Bentonsport area was at or above sea level during a part of the epoch at least, but there is no evidence to show that such was the case during Keokuk times. The flexure may have had its origin therefore in the oscillations known to have occurred in this region during the early part of the Saint Louis.

UNCONFORMITIES.

UNCOMFORMITY BELOW THE SAINT LOUIS.

It has usually been considered that in this region the Saint Louis rests conformably upon the Keokuk beds. Farther north, however, they are known to be uncomformable. At several places in Van Buren county a disturbance of the sedimentation, which may be indicative of unconformity, appears at the juncture of the two formations. This is well shown on Rock creek, near Kilbourne and elsewhere. At this horizon there occurs a confused mingling of calcareous and arenaceous materials, including broken fragments of chert and shells and decomposed limestone. While not decisive, the phenomena suggests that during the time these deposits were forming they were near enough

to the sea margin to be subject to shore influences. This evidence of unconformability is further strengthened by the marked thinning of the Warsaw formation northward. It is probable therefore, that the Iowa-Missouri line appromimately marks the point to which the sea retreated at the close of the Keokuk age, and from which it again advanced northward during the age succeeding.

UNCONFORMITY BETWEEN THE SAINT LOUIS AND DES MOINES FORMATIONS.

The interval between the Saint Louis and the Des Moines or lower coal measure rocks, represented farther southward by the Kaskaskia, is here marked by extensive evidence of prolonged erosion. Exposures showing the discordant relations of these deposits are seen at many places. The following figure illustrates an exposure on Bear creek (Tp. 68 N., R. IX W., sec 10, Sw. qr).

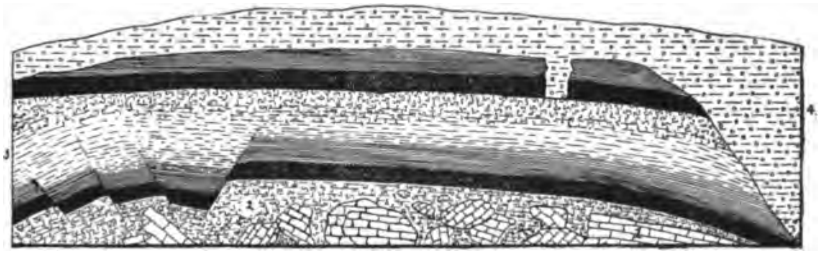


Figure 24. Exposure of coal measures on Bear creek.

In the figure the coal measures are shown resting on the decomposed surface of the Saint Louis limestone. Number 1 is a white granular limestone; 2, residuary clay including more or less decomposed fragments of 1; 3, shales and fire clay including two thin seams of coal, and, 4, surface clay.

The lower coal is here underlain by residuary clay containing fragments of limestone, siliceous rock and chert derived from the underlying limestone. The limestone fragments are much decomposed and coated with iron oxide. They represent the upper white limestone of the Saint Louis. About one hundred yards below this locality the coal measure rocks rest upon the worn surface of the brown magnesian limestone. The following represents an exposure on Coates creek (Tp. 69 N., R. VIII

W., sec. 20, Se. qr.), the coal measure sediments resting in channels cut in the surface of the Saint Louis beds.

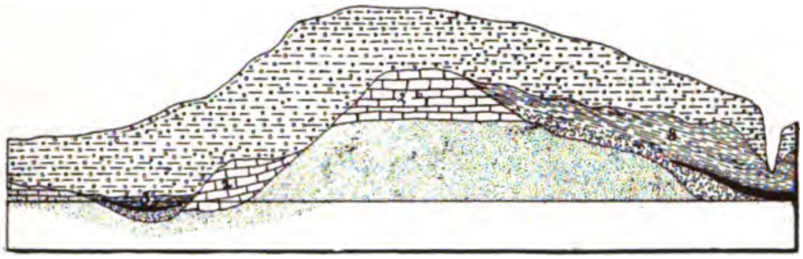


Figure 25. Diagrammatic section on Rock creek (west branch, Tp. 69 N., R. IX W., sec. 24, Nw. qr.), showing erosion unconformity between the Saint Louis and Des Moines formations.

In this figure number 1 is the Keosauqua sandstone; 2, a compact limestone; 3, the coal measure shales and clays with small bits of coal, and, 4, surface clays. Vertical scale much exaggerated.

On Rock creek coal measure shales are seen resting upon the magnesian limestone at the base of the Saint Louis, while the higher members of the same number are well exposed in the bluff a short distance below.

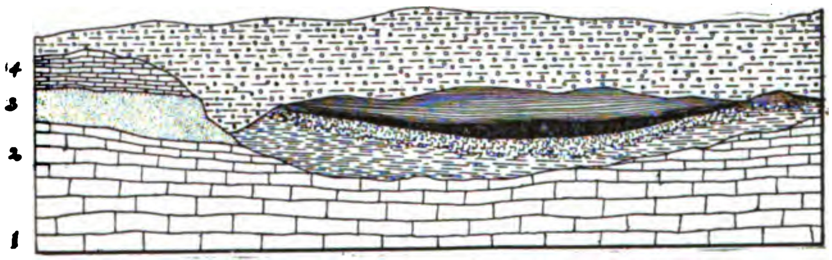


Figure 26. Unconformity below the coal measures on Coates creek.

In figure 26 number 1 represents magnesian limestone (arenaceo-magnesian beds); 2, brecciated limestone; 3, Keosauqua sandstone; 4, compact limestone; 5, bituminous shales; 6, surface deposits.

ECONOMIC PRODUCTS.

COAL.

In the vicinity of Farmington, coal has been mined more or less for many years. On the south side of the river, it was at

one time mined at Boyer's station, but the workings are now abandoned. It is still mined somewhat for local use in the Tp. 67 N., R. VIII W., sec. 3, Se. qr. The most productive areas, however, are on the north side of the river.

North of the river the coal occurs in basins in the limestone. Frequently, at the middle of the basin, the coal is found to rest upon several feet of sandstone and fire clay while towards the edges the sandstone and fire clay thin out, allowing the coal to rest directly upon the limestone. The section from this vicinity appears on page 209. The field, as now known, comprises four separate basins of workable coal nearly all of which has been exhausted. One of these covered ten acres, two about fifteen acres each and one twenty-five acres.

The thickness of the coal varies from four to six feet. The only mine now being operated is located in Tp. 68 N., R. VIII W., sec. 26, Se. qr. It is situated on the hillside about a quarter of a mile north of the railroad track. The top of the shaft, which is fifty feet deep, is about seventy-five feet above the track. The coal is said to vary from four to six feet in thickness.

Coal is mined to some extent for local use at several places along Coates creek. It is here evidently in basins similar to the deposits at Farmington. Mining has also been carried on to some extent on the south side of the river at Keosauqua, as also at Pittsburg. The seams are thin, however, and of rather poor quality.

The only mine along the river between Farmington and Doud's now being worked, is that of Jacob Boyer's on Bear creek, (Tp. 68 N., R. IX W., sec. 3, S. ½). The section here is as follows:

	FEET.	INCHES.
6. Concealed		
5. Coal		6
4. Whitish sand rock, very hard, called "clod" sometimes changes to black shale 6 to	12	
3. Coal	3	
2. Fire clay		3 to 4
1. Sandstone	?	

The rock above the coal is strongly charged with sulphur, and water percolating through it becomes impregnated with acid.

The center of the coal mining industry in Van Buren county is at Douds. Here the coal occurs at a higher horizon than towards the east, a considerable thickness of clay shales separating the coal from the limestone below. Four mines are being operated here, all of which are evidently located in the same basin. The coal is of fairly good quality, though more or less impregnated with sulphur, sometimes in the form of iron pyrites.

Carson's mine is located in Tp. 70 N., R. XI W., sec. 24, Nw. qr. At this mine the coal is obtained by drifting and has been worked more or less for thirty years. The coal averages from three and one-half to three and three-fourths feet in thickness. About thirty acres have been exhausted.

Hugh Findley's mine (Tp. 70 N., R. XI W., sec. 24, Ne. qr.), is situated but a short distance east of Carson's on the opposite side of the branch and was opened in 1892. The estimated area exhausted is about three-fourths of an acre.

Ratcliff's mine (Tp. 70 N., R. XI W., sec. 23, Nw. qr.) was opened in 1892. The section of this mine was given on page 226.

G. W. Findley's mine (Tp. 70 N., R. XI W., sec. 14, Se. qr.) is situated in a small valley, and the coal is reached by a shaft. The approximate area from which coal has been exhausted is about five acres.

A. Hinkle's mine is situated about two miles east of Selma, or Independent (Tp. 70 N., R. XI W., sec. 10, Sw. qr.). The coal occurs but little below the level of the valley, and the thin covering of shale affords a poor roof. About ten acres have been exhausted on the east side of the creek and a new opening on the west side has proven troublesome from the falling of the roof. The air shaft shows the following section:

	FEET.	INCHES.
5. Alluvial clay or sand	10	
4. Shale, bituminous with lenticular masses of black limestone	4	
3. Coal	3	3
2. Iron pyrites		3 to 6
1. Fire clay		

No coal is now mined here, though efforts are being made to put the mine in working order. The coal occurs at about the same horizon as at Douds, and probably belongs to the same basin.

La Fever's mine is situated on the south side of the river (Tp. 70 N., R. XI W., sec. 17, Sw. qr.). The section is as follows:

		FEET
6.	Concealed	?
5.	Coal	1½
4.	Fire clay	3
3.	Shale, bituminous	9
2.	Coal	3 to 3½
1.	Fire clay	

An older drift near by has been worked intermittently for about twenty years. Coal has been taken out also on the farm of Mr. Beitti in the southeast quarter of section twenty (Tp. 70 N., R. XI W.). The supply was limited, however, and is now exhausted. The bed is said to have been abruptly terminated by yellow clay evidently indicating a preglacial, drift-filled channel.

At the Overturff's coal bank the upper bed of coal (p 226), evidently belongs to a higher horizon than the preceding. Very little effort has been made to mine this coal and its extent is unknown. About one-half acre has been exhausted. No mining is being done here at the present time. Some coal has been taken out on section five and six in the Lick creek township, which may represent the Overturff seam. A seam two feet thick on the farm of John Beal is mined somewhat for local use.

Mathias coal bank is located in Tp. 70 N., R. X W., sec. 17, Ne. qr., and has yielded a limited amount of coal for several years. A new opening now being made on the hillside furnished the following section:

		FEET.	INCHES.
8.	Clay, red	33	
7.	Sand	4	
6.	Coal		7
4.	Limestone, brown	2	9
5.	Limestone, blue	1	3

		FEET.
3.	Shales, black, somewhat massive; with limestone "boulders"	2
2.	Coal	3
1.	Fire clay	15+

The so called fire clay here is probably in part shale. This may be correlated with the Doud's coal. About an acre has been worked out here. This same seam has also been worked about half a mile farther east, on the farm of T. G. Moyer, but the opening has been abandoned for several years.

Fuller's coal bank is an opening made by F. B. Smith, of Birmingham, in a seam cropping out on the land of Charles Fuller. (Tp. 70 N., R. X, sec. 26, Ne. qr.) The section is as follows:

		FEET.	INCHES.
6.	Concealed	?	
5.	Shale, bituminous and sandy	8	
4.	Sandstone, somewhat ferruginous with coaly seams	4	
3.	Shale, bituminous		5
2.	Coal	2	8
1.	Sandstone, blue	4	

Very little coal has been taken out here as yet, and no inference can be made as to the extent of the bed, or its relation to other basins. East of this, on the east branch of Brick creek there occurs a coal seam which apparently represents the same horizon.

Taylor's local bank is in the northeastern part of the county. Coal has been mined here (Tp. 70 N., R. VIII W., sec. 14, Nw. qr.) for thirty-five years. An exposure shows the following arrangement:

		FEET.	INCHES.
8.	Concealed	15 to 25	
7.	Shales, black, fissile	1	6
6.	Sandstone, ash gray, irregularly indurated	1	
5.	Coal, includes lenticular layers of sandstone	2	
4.	Shale, black, fissile, calcareous		10
3.	Fire clay	3	
2.	Concealed	5	
1.	Limestone, in bed of creek (Saint Louis)		

In an old opening near by, the coal occurs in two benches aggregating over six feet.

		FEET.
4.	Shale, black, forming a good roof	4
3.	Coal	4
2.	Shale, black, coaly	1
1.	Coal	2¼

This, however, is a local development, as adjacent openings do not show more than three feet. The amount of coal mined here is limited to the local demand, and the area exhausted probably does not exceed an acre. No reliable estimate can be made of the extent of the basin, though it is probably limited. This locality was visited by Worthen in 1856*.

The Yargus coal bank is situated about a mile southeast of Taylor's bank (Se. qr. sec. 23). The coal is about three feet thick and rests upon the Saint Louis limestone with three or four feet of fire clay between. About two acres have been exhausted. The coal is mined intermittently for local use only. The rise of the limestone in the creek bed toward the west suggests that this coal lies in a basin which may or may not be connected with that of Taylor's bank. Toward the east, coal, probably belonging to this same basin, is mined to some extent, near the county line at Cox's bank and elsewhere.

CLAYS.

CHARACTER AND DISTRIBUTION.

The clay industry of Van Buren county has not reached so important a development as in the neighboring counties. This has been the result of the relative abundance of good quarry stone rather than the absence of suitable material for the manufacture of building brick.

The county affords four series of clays which are to a greater or less extent available. These are coal measure, drift, loess and alluvial clays. The Mississippian series as exposed in this county rarely yields any clay available for manufacturing purposes.

*Geology of Iowa, vol. 1, p. 151. Albany, 1858.

The coal measures are widely distributed throughout the county. They are very largely composed of shales of various kinds. The bituminous shale so commonly found in connection with coal seams is of small value. The grey, blue and drab shales may, however, usually be found and are almost always of excellent quality for the manufacture of pavers, as well as for building brick, and the finer grades of face brick. Fire clay is here, as usual, found in connection with the coal seams. It may be used for brick, refractory material or pottery. There are at present two potteries in the county which obtain their material from this source.

The drift clays are as usual full of disseminated gravel which lessens their value. Both the blue and yellow clay is, however, at certain points of sufficient purity to be available.

The loess of this county occurs as a thin sheet spreading over the uplands. While it is not so thick here as in many other counties of the state, it presents the same characteristics which have caused it to be so widely used. Its very general distribution and the fact that it is so easily treated, and is adapted to so wide a variety of uses, makes it especially valuable.

The alluvial material developed along the Des Moines and Fox rivers, and to a less extent along the smaller streams has already been used to a certain extent. It is an abundant source of material for the commoner and cheaper forms of building brick. It is especially adapted to the manufacture of hand brick, and could be used here much more widely than has thus far been attempted.

CLAY INDUSTRIES.

KEOSAUQUA.

Charles Schreckengost in 1893 began the manufacture of brick from a drift clay. The material is crushed and mixed in a horse power mud mill and moulded by hand. The bricks are burned in open kilns. They are of fair quality though rather porous. The trade is local. H. A. Whitmore also manufactures a hand brick from surface soil taken to a depth of about eighteen inches. The bricks are burned in open kilns and used locally. A few have been shipped to other points in the county, the

Farmer's Savings Bank at Farmington being built of this brick made at this yard.

VERNON.

The Vernon pottery is located on a hill south of town. It is operated by Mr. R. M. Dickson and has been running for fifty-two years. In addition to jugs, jars, milk crocks and other forms of pottery, small quantities of sewer pipe and of fire brick are made. The clay is obtained from the coal measures about three miles from the pottery. It is of good quality and works up nicely. A total of about 140,000 gallons represents a years output. The wares are shipped throughout this and neighboring counties and find a ready sale. About thirteen skilled workmen are employed.

BONAPARTE.

H. A. Whitmore burns brick at Bonaparte. Soil is used being taken to a depth of eighteen inches. The bricks are hand moulded and burned in cased kilns. The trade is local.

FARMINGTON.

J. F. Leavitt began in 1894 the manufacture of brick at Farmington. Alluvial clay is used. The material is mixed in a horse power pug mill and the common or stock bricks are moulded by hand. The face brick is repressed on a hand power perfection press and the ware is burned in cased kilns. A good product is being turned out.

W. Wen. In east Farmington just north of the Chicago, Burlington & Kansas City railroad bridge is a pottery opened in 1894. The material is obtained from the shales of the coal measures and is crushed on a horse power, Akron, Ohio, machine. The ware is burned in one up draught kiln having a capacity of 1,500 gallons. Flower pots and drain tile have so far been made. The latter is made on a hand power machine of English make.

CANTRIL.

The Cantril Brick Company has been in operation since 1891. They use a surface clay, mixed in a horse power pug mill, moulded by hand and burned in up draught kilns. The clay shrinks considerably in drying and burning, but forms a

tough, hard hand brick of good color. Haney Brothers also manufacture brick from a similar clay by the hand process.

MILTON.

Sylvester Fogelsong began at Milton in 1893 the manufacture of brick from surface clay by hand process. Homer Powers also makes brick here from a similar clay, having burned his first kiln in 1894.

BUILDING STONES.

Limestone and sandstone for ordinary masonry occur in inexhaustable quantities all along the Des Moines river.

LIMESTONES.

Limestone suitable for heavy masonry is abundant in the arenaceo-magnesian beds of the Saint Louis, while the Keokuk beds at Bentonsport have supplied large amounts. The concretionary character of the magnesian beds, however, interferes with the working of the stone, and unfits it for use where dressing is required. The beds are usually thick, and present considerable difficulty in quarrying except where worked on a large scale. These beds were quarried quite extensively at many places along the Des Moines for the construction of dams in the days of river improvements, for which purpose the rock was well adapted. The white limestones are drawn upon more generally for ordinary building purposes. The hardness of the rock, however, precludes its use where a dressed stone is required.

DOUDS.

About two miles east of Douds (Tp. 70 N., R. X W., sec. 31, Nw. qr.), the Saint Louis limestone was in 1894 opened up for quarrying. The stone, however, proved to be of inferior quality and only a small amount was taken out.

KEOSAUQUA.

The white limestone is quarried at several localities near Keosauqua. On Thatcher's creek, one and a half miles south (Tp. 68 N., R. X W., sec. 2, Sw. qr., Se. ¼), Mr. Manning has taken out stone at several points on both sides of the creek.

Stone has also been taken out on east Thatcher creek (Tp. 68 N., R. X W., sec. 1, Se. qr.). The stone at all three quarries is of the same lithological character. East of town on the north side of the river (Tp. 69 N., R. IX W., sec. 31, Sw. qr.), is the S. D. Fellow quarry, also in the Saint Louis. This quarry has been operated for the local trade some twenty-five years. The ledges are twelve to fifteen inches thick and suitable for foundation and rough building purposes.

ROCK CREEK.

Stone has been taken out along Rock creek at two or three points (Tp. 69 N., R. IX W., sec. 21, Nw. qr., Ne. ¼). The rock belongs to the Saint Louis and so far has only proven suitable for local foundation work.

BENTONSPORT.

The Keokuk limestone was extensively quarried at Bentonsport about eight years ago for bridge building and riprap. In the winter of 1893-4 about 1,000 cubic yards were taken out and used to protect the piers of the bridge which were then decaying. Since then no stone has been quarried. Only the upper ledges are used. Three-quarters of a mile east of Bentonsport (Tp. 68 N., R, IX W., sec. 1, Se. qr., Ne. ¼) the Chicago, Rock Island & Pacific railroad has taken out a small amount of stone from equivalent layers. The quality is poor and none is now used.

BONAPARTE.

Directly across from Bonaparte (Tp. 68 N., R. VIII W., sec. 17, Nw. qr., Nw. ¼) a small amount of stone was quarried some years ago, but the quarry was never extensively developed. The main quarries are on the north side of the river and have been worked for twenty-five years or more. The quarries are on Reed's creek and supply a good stone which dresses well. It has been used for the engine room of Meek Brothers woolen mill and the piers of the Bonaparte bridge. It is also used extensively for local work furnishing foundation stones, window sills and caps, and well and cellar rock. The stone comes from the arenaceo-magnesian division of the Saint Louis.

A short distance east of town the Keokuk limestone is occasionally quarried for local purposes. A section here (Tp. 68 N., R. VIII W., sec. 9, Se. qr., Sw. ¼) showed the following layers:

		FEET.
3.	Drift	3
2.	Limestone, blue, irregular, thin bedded; intermixed with layers of shale; fossiliferous, cherty	7½
1.	Limestone, blue, hard, cherty, thick bedded; main quarry rock; exposed	6
		16½

The stone is very hard to work. Farther up the creek the fine grained yellow limestone occurs but has not been developed. Still farther east (Tp. 68 N., R. VIII W., sec. 15, Ne. qr.) Meek Brothers formerly quarried a small amount of rock.

FARMINGTON.

The south-western drift-covered portions of the county is largely supplied with rock from the Indian creek quarries near Boyer (Tp. 67 N., R. VIII W., sec. 5, Ne. qr., Nw. ¼). A section seen here showed:

		FEET.	INCHES.
4.	Drift	3	
3.	Limestone, shaly with interbedded clay seams		6
2.	Limestone, grey, coarse sub-crystalline	2	6
1.	Limestone, fine grained, smooth, with conchoidal fracture; pure above, coarser and more impure at base	5	10

Stone has been quarried here for many years for building and rip-rap. The stone is too hard to dress nicely and is used mainly for rough masonry, caps and sills.

Chequest Marble. On Chequest creek a ledge of the Saint Louis limestone near the middle of the formation has been utilized to some extent for tombstones, and is known as Chequest marble. It consists of a compact, dove-colored limestone and is susceptible of a good degree of polish. It was from this bed that a block was sent by the citizens of the county for use in the Washington monument.

SANDSTONES.

On Bear creek south of Bentonsport (Tp. 68 N., R. IX W., sec. 11, Nw. qr.), the blue sandstone of the arenaceo-magnesian beds has been quarried for many years. While the rock is sometimes of poor quality, excellent stone for window sills and like uses is obtained from this locality. A good development of these "sandstones" occurs also at Price's, now Rockdale quarry, three miles west of Pittsburg. The stone appears to be of good quality. Some of the foundation stone for the bridge at Pittsburg was obtained here. The section in the quarry (Tp. 69 N., R. X W., sec. 20, Sw. qr.), showed the following:

		FEET.
3.	Drift	4
2.	Limestone, fine grained, arenaceous, compact; weathering yellow	10
1.	Limestone, light colored, arenaceous, fine grained hard; exposed	3½

The stone is now used only for rough masonry. The brecciated beds and the white limestones sometimes furnish ledges that may be utilized for the manufacture of lime. Kilns were formerly in operation on Indian creek, near Keosauqua, at Bonaparte and several other points.

SOILS.

The soils of the county may be classified as loess and drift soils, and alluvial soils. Of these the former covers by far the greater portion of the county. The thin mantle of loess covering the divides both north and south, constitutes the best soil of the region, where the drainage is sufficient to remove the excess of surface waters. The broad level plateaus in the northeastern part of the county have proven intractable in places owing to insufficient drainage. By the adoption of better methods in farming, these areas are being brought under cultivation and will eventually prove as valuable as any of the lands in the county.

Along the slopes where surface erosion has removed the mantle of loess, the soil is in large part derived from the underlying yellow drift clays, with a portion of the loess which has

crept down the hillsides. In these cases the inferior character of the soil is in part compensated by improved drainage. These slopes are therefore usually well wooded, but are not well adapted for tilling. Where the drift clays contain a considerable proportion of sand they are much improved as a soil, owing to their greater porosity. In some cases over the plateau, the loess is so reduced in thickness that the yellow clays practically lie at the surface. In this case the fertility of the soil is largely dependent upon the proportion of sand which it contains. The buffalo licks are such areas of limited extent in which clay predominates to such a degree as to make the soil scarcely tillable.

The alluvial soils are well developed along the Des Moines and Fox rivers, and to a lesser extent along the larger of their tributaries. The bottom lands of the Fox are in large part unavailable for cultivation on account of being subject to overflow. In places also they are underlain by a dense tenacious clay soil termed "gumbo," which is almost wholly intractable. If the drainage of these areas could be controlled, they would doubtless prove valuable for tillage. As it is they are largely devoted to grazing, and by careful attention they may be available for hay. Along the Des Moines valley, the soils are characterized by a much greater proportion of sand than elsewhere. The flat areas, as at Keosauqua, represent the location of the overflow swamps at the time the terraces were forming along their border. These were originally wet and swampy, but now furnish a fairly good soil, though less valuable than that of the upland plateau.

ROAD MATERIALS.

Abundant material for the improvement of roads occurs along the Des Moines and its tributaries. The limestone beds furnish inexhaustible supplies of material for macadamized roads, while sand may be had in abundance along all of the larger streams of the region. A short distance east of Farmington there is a gravel pit which has furnished considerable ballast for the Chicago, Burlington & Kansas City railway. The greatest depth worked is eighteen feet. Of this, eight feet near

the top of the section is of coarse gravel. The remainder is a coarse, beautifully cross-bedded sand containing pebbles. Directly south of here is a second pit twelve feet deep which belongs to the Chicago, Rock Island & Pacific railway. It was opened in 1879 and has furnished ballast for about twenty-five miles of track.

MINERALS.

Pyrite. Iron pyrites is sometimes abundant in the coal and shales of the coal measures and to a less extent occurs also in the limestones and shales below. It occurs in the former usually in concretionary masses of yellow metal with crystal forms. Good crystals are sometimes found in cavities in the black limestones occurring above the Douds coal. In the limestones and shales of the Lower Carboniferous rocks, pyrites sometimes occurs in small crystals and lumps, but is more commonly disseminated in grains through the rock.

Calcite. Beautiful crystals of calcite frequently line the interior of the hollow spherical concretions termed geodes which characterize the geode shales of the Keokuk formation. These geodes are usually abundant along the lower courses of the streams intersecting these shales, in the vicinity of Bentonsport and Bonaparte. Dog tooth spar is also sometimes found lining small cavities in the shales above the Douds coal. Calcite also occurs associated with the filling of irregular cracks in these limestones.

Sphalerite is occasionally found in geodes. This mineral is also found in the drift.

Selenite. The black limestone over the Douds coal seam contains small amounts of selenite in thin tabular crystals.

WATER SUPPLIES.

For water the chief dependence is placed upon the shallow wells confined to the drift deposits. Along the Des Moines, the river constitutes an unfailing source of supply for general and stock purposes, but at a distance from the stream considerable difficulty is often experienced, as the wells cannot be relied upon for a very large supply during the summer months. In a few cases drilling has been carried down into the Lower

Carboniferous rocks, as at the Edmonson, Davis, Miller and other wells. In only one of these, however (Miller's), has a satisfactory supply of water been obtained. The only flowing wells in the county are along the Des Moines; one at Farmington, and one at Bonaparte. These holes were put down in search for oil or gas, and failing they were abandoned. There has been no attempt made to use the water supply, and no record of these wells is now available.

At Keokuk, several flowing wells occur, ranging in depth from 740 to 1800 feet. The first flow comes from a sandstone presumably belonging to the Niagara series, at about 737 feet from the top of the bluff, or about 100 feet below sea level. Additional flows are obtained at intervals from 1200 to 1800 feet. The water from the lower beds shows a less proportion of iron and other mineral ingredients than that from the higher strata. As Van Buren county does not differ essentially from Lee county in its geological structure, it is quite probable that adundant supplies of water may be obtained anywhere in the county at from 700 to 900 feet, according to the location of the well. The water at this horizon is quite highly charged with mineral, however, and may not always prove wholly acceptable for general use.

The height to which the water will rise has not been tested at Keokuk but it flows with strong force at an elevation of 638 feet. At Mount Clara which has an elevation of 679 feet, the water in W. J. R. Beck's well, which is 939 feet deep, rises to within six feet of the surface corresponding to an elevation of 673 feet. If there is no escape of water above the rock surface here, this altitude may be considered to represent the level to which water from the same horizon (Niagara) will rise throughout the region. As to the lower water-bearing beds, nothing is known in this regard, though they may possibly have a higher head. In testing for flowing wells, therefore, the elevation of the locality must be taken into consideration. From the table of elevations on page 202 it is seen that the plateau level varies from 750 to 800 feet, and hence flowing wells cannot be looked for here from the Niagara horizon, unless they start in depressions from eighty-five to one hundred and fifty feet below the

general plateau level. Evidently no difficulty should be encountered in obtaining flowing wells within the Des Moines valley. Whether the lower beds will give flowing wells on the uplands remains to be tested.

ACKNOWLEDGMENTS.

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GEOLOGY OF KEOKUK COUNTY.

BY

H. FOSTER BAIN.

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CONTENTS.

INTRODUCTION.

LOCATION AND AREA.

Keokuk county lies in the southeastern portion of the state, and is bounded on the north by Jasper, Poweshiek and Iowa counties, on the east by Washington, south by Wapello and Jefferson, and west by Mahaska. It is nominally twenty-four miles square, but owing to errors in the earlier surveys it contains slightly more than that area, having in all about 370,000 acres. The county presents a considerable diversity of geological details.

PREVIOUS WORK.

For a county so well supplied with mineral wealth, there is a remarkable dearth of information regarding its geologic structure. The work of the earlier surveys under Owen and Hall was not extended into this county. White* made reference to the presence in it of both coal measure and sub-carboniferous rocks, but no detailed work was done by him in this region. Gordon† has published notes upon the strata passed through in the deep well at Sigourney. With these two exceptions nothing had been published upon the geology of this county previous to the organization of the present survey.

PHYSIOGRAPHY.

TOPOGRAPHY.

If one had a topographic model of this county to examine, probably the most notable feature exhibited by it would be the broad contrast between the northern and southern portions. In general the whole county may be considered an approximately level plain into which the streams have cut their valleys. The greater number and larger size of the streams in the southern part, however, cause it to appear rough and broken, and while this is naturally more marked in a detailed than in a general way, it does not entirely disappear even when the general view is considered. Thus it happens that the northern and

*Geology of Iowa, vol. II, p. 267. Des Moines, 1870.

†American Geologist, vol. IV, pp. 237-239. Minneapolis, 1889.

northeastern portions of the county are predominantly upland as compared with the remainder.

This northern portion presents to view a broad open plain rising in a succession of low billows varying usually from ten to twenty-five feet in height and succeeding each other at intervals of from one-quarter of a mile to one mile in distance. Sharp contours are rare except in the immediate vicinity of the streams. The land rises gently from 875 feet above sea level at the east to 910 at the west county line. Across this plain the

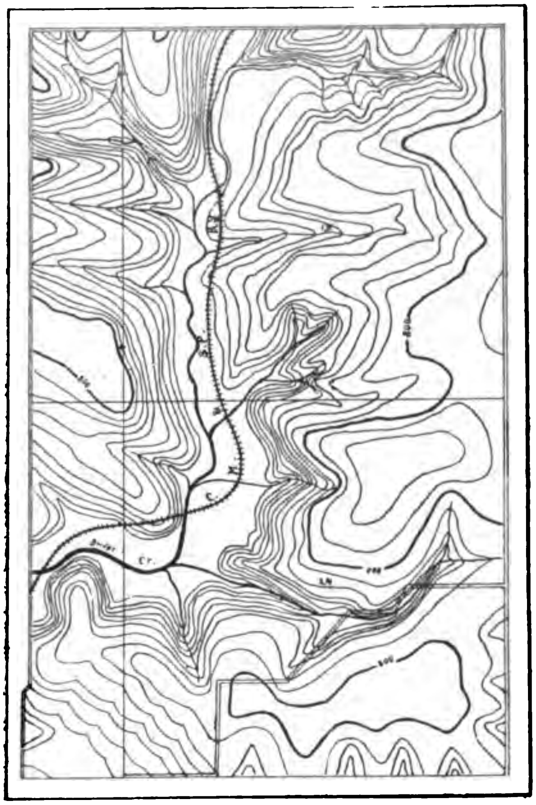


Figure 27. Topographic map of the region near Rowley's mine, north of Sigourney. Contours 10 feet; scale 2 inches to the mile.

streams run in direct courses, with narrow valleys bounded by low rounded bluffs and bordered by a fringe of timber which becomes a notable feature of the landscape.

In the central and southern parts of the county the topography becomes more rugged. The number of streams here increases and they with their feeders have cut deeper channels. The country is more wooded and the landscape loses its simplicity. Along the streams deep gorges and high bluffs alternate with broad savannas. Sharp contrasts are presented and all the results of the long action of a complex dentritic system of drainage are encountered. Yet through all whenever a commanding view may be obtained the general aspect of the plain is still presented. A noteworthy fact is that when in the southern portion of the county a plain is encountered, it is exceedingly level. In detail it shows no great difference in elevation. It stretches away in places three or four miles without a change in altitude of more than ten or a dozen feet. As the streams are approached there is a greater ruggedness than in the northern area. Differences of from twenty-five to one hundred and twenty-five feet are met with in as many yards or even feet; and a succession of ridges and hills succeed one another, each lower than the other until the stream is reached. The contrasts of this region are well shown in the profile of the section from Keota to Atwood (figure 3, plate viii) and a characteristic example of the relief of the region is shown in the annexed map.

The mean elevation above sea level for the entire county is in the neighborhood of 800 feet. The greatest elevation now known is 910 feet, and the lowest 657 feet. The difference between any two points is nowhere great. The following table, in part compiled from railroad levels and in part determined during the course of the present survey, exhibits the levels of the principal towns and villages as well as of some other points of geological interest. In each case the authority upon which the figures are based is given.

Table of Elevations.

LOCALITY.	Elevation.	AUTHORITY.
Atwood	721	C., R. I. & P.
Atwood quarry	738	C., R. I. & P.
Bridge creek east of Sigourney	693	C., R. I. & P.
Bridge creek north of Sigourney	713	C., M. & St. P.
Cedar creek at crossing C., R. I. & P., three miles east of Delta	693	C., R. I. & P.
Clear creek at crossing C., R. I & P	743	C., R. I. & P.
Cuba	745	C., M. & St. P.
Delta	802	C., R. I. & P.
East county line two miles from Kinross	772	B., C. R. & N.
English, river Cuba	725	C., M. & St. P.
German creek at crossing C., R. I. & P	688	C., R. & I. P.
Harper	818	C., R. I. & P.
Hayesville	792	C., M. & St. P.
Hedrick	820	C., M. & St. P.
Highland between German and Bridge creeks three miles east of Sigourney	788 808	C., R. I. & P.
Keota	876	C., R. I. & P.
Keswick	792	B., C. R. & N.
Kinross		B., C. R. & N.
Nassau	900	B., C. R. & N.
North English	794	C., M. & St. P.
North Skunk, Atwood	695	C , R. I. & P.
North Skunk, Delta mill	682	Survey.
North Skunk, South Sigourney	658	City levels.
Nugent	833	Survey.
Pekin	865	Survey.
Showman	691	C., M. & St. P.
Sigourney	768 796	C., R. I. & P. C., M. & St. P.
South English	844	B., C. R. & N.
South Skunk, North Hedrick (bridge 677.)	657	C., M. & St. P.
Thornburg	882	B., C. R. & N.
Tilton	849	C. & N. W.
Webster	862	B., C. R. & N.
West county line one mile west of Nassau	910	B., C. R & N.
What Cheer	760 788	B., C. R. & N. C. & N. W.

DRAINAGE.

The drainage of the county is quite unequally divided between two systems. The northern tier of townships contributes to the South English river which forms a branch of the English river system, while the English river is itself tributary to the Iowa. This system drains in Keokuk county an area of about 100 square miles, all within the northern tier of townships and distributed approximately as follows:

	SQUARE MILES.
Liberty township	30
English River township	26
Adams township	24
Prairie township	20

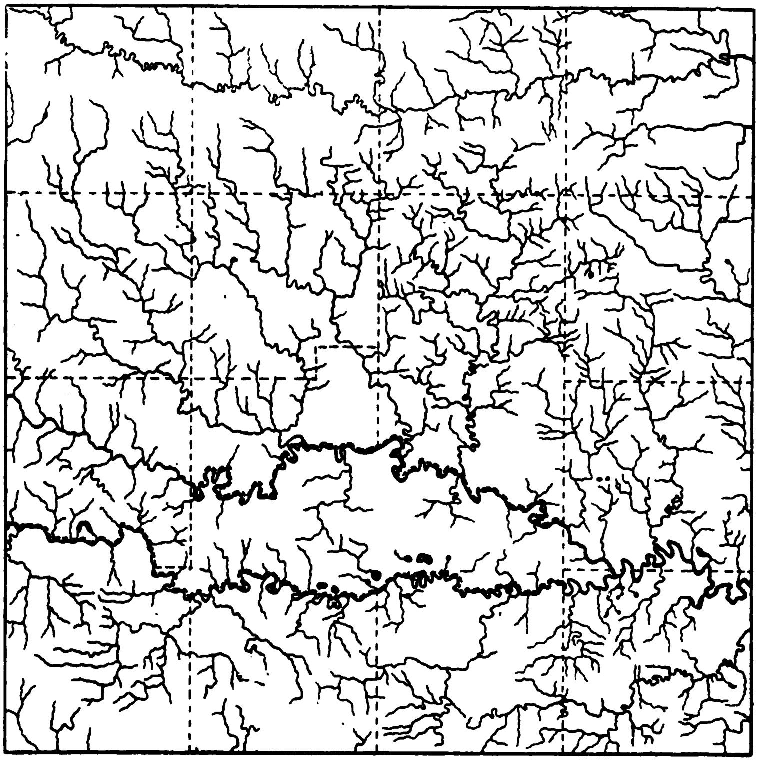


Figure 28. Sketch map showing the drainage of Keokuk county.

The streams of this system flowing in Keokuk county comprise South English, Little creek, Smith creek and a few minor tributaries of South English river. The main stream enters the county at the northwest corner and, flowing first slightly south of east, and later returning north, crosses the east county line near the north extremity, without having at any place wandered more than three or four miles from the northern boundary. Through its entire course it meanders but slightly from its main direction. In a more minute consideration it is

to be noted that the river makes but few bends and that these are small. A general absence of broad bottoms, of ox-bows, lagoons and of high steep bluffs, is also noticeable. Another striking characteristic is the small number and small size of tributaries, these rarely being more than five miles in length and of such insignificant size as scarcely to deserve an independent name. Few outcrops of rocks occur along its course, only one or two being known. The alluvium of the bottoms is confined to a shallow, narrow area in the immediate vicinity of the stream. Through the greater part of its course the stream runs over drift which also forms its bank and rises with rounded contours from twenty-five to one hundred and ten feet above the water level. The watershed between the English and Skunk rivers follows the former closely and recedes from the latter. The Skunk has sent out long arms which drain territory apparently properly belonging to the South English. All these facts point to one conclusion; that the South English is a comparatively young stream. It seems clear that the origin of this river dates from postglacial times.

The watershed between the two river systems of this county is not a marked topographic feature. Indeed it might be crossed again and again without attracting attention. The upland prairies are, as has been said, of considerable regularity. A careful scrutiny is all that reveals the direction of the drainage. On the whole it is noticeable that the country slopes gently to the south from the divide. Numerous broad, shallow valleys open out in that direction. On the other hand toward the north the prairie remains level up to almost the very brink of the South English river; the tributary streams being small and unimportant. In this regard the South English river shows well the characteristics of the rivers of the loess-drift region as pointed out by McGee* in that it is a river with a long, narrow basin, and flows along the southern edge of a gently sloping plain.

The greater part of the drainage of the county is effected through the Skunk river. This includes within the limits of the county both the North and South Skunk branches which unite about four miles from the east county line. Both

*Eleventh Annual Rep. U. S. Geol. Surv., pt. 1., pp. 411-415. Washington, 1893.

forks of the river receive numerous tributaries. Among those flowing into the North Skunk are German creek, Bridge creek and Cedar creek. Into the latter flow Whiskey Run, Coal, Rock and Smith creeks. Sugar creek, Steady Run and Rock creek flow into the South Skunk; while East Cedar, Crooked and Richland creeks eventually find their way into the main river. Most of these streams are rather large and important, cutting their way below the general level to a considerable depth. German creek, four miles above its mouth, is nearly 250 feet below the adjoining uplands. Between German and Bridge creeks the land is 115 feet above German creek, but Bridge creek lies over 100 feet below this level. Cedar creek is more than 200 feet lower than the upland upon which the town of Delta is built, and the Skunk river is about 120 feet below Sigourney, though that place is fifty feet below the general level of the upland east of it, and 100 feet or more below the high prairie of the northern part of the county.

In considering the Skunk river all the features mentioned in connection with the English river are found absent. The Skunk exhibits a notable sinuosity. Neither in general nor in detail is its course straight. It turns and twists in a most complex manner. It has a large number of deep and important tributaries which reach out and drain approximately 476 square miles in this county. Broad, alluvial bottom lands, from two to six miles wide, with shallow lakes or ponds, bayous and ox-bows are not infrequent. Numerous rocky outcrops are found, and these are cut through, forming in places high, picturesque bluffs. There are evidences at numerous points of changes in the position of the channel. The river has been thrown now to one side and again to the other. It has in places made cut-offs, leaving what were once islands, but now appear only as isolated hills in the midst of the flood plains. An interesting example of this is seen north of Richland. At this point the river formerly ran nearly a mile north of its present channel. The change made has left a small hill rising out of the flood plain.

There is little evidence in this region showing that these changes are due to reoccupation of a preglacial channel. No

evidence of a larger channel cut out in the limestone and filled in with drift has been noted in this county. The stream seems to have cut its present channel since the drift was laid down. This is of interest in view of the considerable size of the stream, and the complex drainage system which must have required for its development a considerable time; a period in excess of that required by the streams in the northern part of the county.

STRATIGRAPHY.

General Relations of Formations.

The surface materials of the county are almost entirely of glacial origin. The areas over which the the hard, underlying rocks are exposed are limited, and are confined chiefly to the bottom of the principal streams. Away from these the drift almost completely conceals the indurated rocks. The geological formations present in the county and their stratigraphic relations, may be best shown by the subjoining synoptical table.

Classification of Formations.

GROUP.	SYSTEM.	SERIES.	STAGE.	SUB-STAGE.
Cenozoic.	Pleistocene.			Alluvium Loess. Drift.
Paleozoic.	Carboniferous.	Upper Carboniferous.	Des Moines.	
		Mississippian Lower Carboniferous.	Saint Louis.	Pella. Verdi. Springvale.
			Augusta.	Keokuk. Burlington.

DEEPER STRATA.

As will be seen from the above the range of geological time represented by the rocks exposed within the limits of this county is not great. In all, but two of the great periods are represented, and knowledge of the earlier history of the county can only be derived from deep borings.

During the summer of 1888, a deep well was drilled at Sigourney*. Captain Parker, who was at that time mayor, carefully preserved samples of the different strata passed through. These samples have recently been re-examined, and form the basis of the following notes. While the unreliability of records derived from the ordinary or churn drill is fully recognized, it is believed that the care with which these samples were selected and preserved, at least considerably reduces that element of doubt as to the correctness of the record. Previous accounts of this record have been published in the local newspapers. Recent studies in this region, as well as a revision of the material, give considerable information not available at that time.

The following table represents the record as recently determined, as well as the interpretation:

1- 98	Earthy matter	98	Drift	98
98- 120	Limestone, impure, earthy	22		
120- 135	Limestone, cherty	15		
135- 155	Shale, calcareous	20		
155- 165	Limestone and shale	10		
165- 170	Limestone, hard, bluish grey	5		
170- 187	Limestone, cherty, light	17	Saint Louis	89
187- 189	Shale	2		
189- 314	Limestone, hard, white with brown particles	125		
314- 315	Shale, dark green	1		
315- 356	Limestone, greyish white to drab, Rynchonella at 342 feet	41	Augusta	168
356- 554	Shale, soft, green	198		
554- 556	Limestone	2		
556- 585	Shale, soft, green	29	Kinderhook	229
585- 835	Limestone	250	Devonian	250
835- 865	Sandstone	30		
865- 871	Limestone	6	Niagara	36
871-1030	Shale, blue argillaceous	151	Maquoketa	151

*Proc. Iowa Acad. Sci., vol. I, pt. iv, pp. 36-38. Des Moines, 1894

1030–1275	Limestone	245	
1275–1281	Shale	6	Trenton and
1281–1315	Limestone	34	Galena 285
1315–1430	Sandstone	115	Saint Peter 115
1430–1717		287	
1717–1888	Limestone	171	Oneota.

A comparison between this and the previously published record* shows several discrepancies. The drift is in both cases given as 98 feet deep. The next 89 feet is now referred to as the Saint Louis, whereas it was formerly regarded as Keokuk. There are many reasons for this change. In the first place, an examination of the samples shows that the beds are not such a single homogeneous limestone as represents the Augusta of this region, but are made up of alternating bands of limestone and shales such as compose the Saint Louis. It is also worthy of note that the particles of limestone preserved are of the fine grained, compact character and ash to brown color, so constantly seen in the Saint Louis of this immediate region, and not of the coarser crystalline variety shown in the nearest exposures of Keokuk. The topographic features also bear out the assumption. A line of levels shows that the mouth of the well is 118 feet above the bed of the river two miles south of town. Saint Louis limestone is exposed along the river, reaching here a height of nearly twenty feet, or about what it would be if on a level with the strata found in the wells which are referred to the same age.

The two limestones found in southeastern Iowa, and long known as the Keokuk and Burlington, are regarded as members of the same formation, to which the name of Augusta has been given. Worthen, in his notes on Washington county, calls attention to a remarkable thinning out of the Keokuk, it being greatly reduced or entirely absent over the regions studied. This observation has recently been completely substantiated, not only for Washington, but for Keokuk county. These facts taken together, all point to the same conclusion: that the first eighty-nine feet of limestone pierced belongs to the Saint Louis, while the Keokuk is represented merely in a small portion of the upper part of the succeeding 168 feet of strata. The

*Gordon: Am. Geologist, vol. IV, pp. 237-239. Minneapolis, 1889.

two bands of heavy limestone comprised in the strata thus referred to the Augusta, are closely similar in lithological character, and resemble the Augusta limestone of the region as nearly as can be determined.

At a depth of 342 feet a fossil *Rhynchonella* sp. und., was brought up, this being the only form preserved. Below this point the element of uncertainty becomes greater. The succeeding 229 feet of shale is probably all referable to the Kinderkook. The 250 feet of limestone which succeeds is most probably Devonian. The succeeding 30 feet of sandstone and 6 feet of limestone are more probably Niagara, since Calvin has shown that the Niagara at Washington is arenaceous.

The Maquoketa shale seems, by comparison with neighboring records to be well recognized.

The heavy limestone band, 285 feet, succeeding the shale is probably representative of the Trenton and Galena, though it seems impossible to draw a good line between them.

The 115 feet of sandstone which succeeds seems to be the Saint Peter. Beneath this for some distance no samples were obtained as the current of water struck was so strong as to wash away all the drillings. The lower portion of the well yielded samples which, on examination, proved to be limestone as Gordon surmised, and not sandstone as published. This seems to clearly prove that the well ended in the Oneota, though the top of the formation was not definitely located nor was it penetrated, so that its thickness under this portion of Iowa is as much a problem as ever.

STANDARD SECTIONS.

The following sections, chosen from a large number exposed within the county, represent typical exposures of the formation as occurring here.

MANHATTAN MILL SECTION

		FEET.
6.	Sandstone, quartzose, in part calcareous, yellow, soft	1½
5.	Limestone, finely brecciated	1
4.	Limestone, compact, grey, cherty	20
3.	Limestone, earthy, brown, containing numerous chert nodules	15

		FEET.
2.	Limestone, coarse, sub-crystalline, blue and grey in color, fossiliferous; in ledges 9 to 20 inches thick, separated by clay shales 6 to 8 inches in thickness; bands of chert nodules 3 to 10 inches thick near the top	26
1.	Limestone, as above	14

Number 1 of the above section is Augusta and is seen in the Weber quarry near the mill; number 2, also Augusta, is the stone formerly worked in the Cook quarry on Rock creek; number 3 is exposed above the quarry track and represents the Springvale beds; numbers 4 to 6, representing the Verdi beds, are exposed along the railway track (Tp. 74 N., R. XI W., sec. 15, Ne. qr., Nw. ¼) leading to the Cook quarry.

NUGENT SECTION.

(Tp. 74 N., R. XII W., sec. 12, Ne. qr.)

		FEET.
4.	Sandstone, soft, with alternating layers of grey cherty limestone	18
3.	Sandstone, massive, soft	10
2.	Limestone, grey, fine grained	10
1.	Unexposed to water	10

These beds may be recognized as middle Saint Louis (Verdi beds). They are exposed in an old quarry from which the stone used in the construction of the neighboring bridge over Skunk river was evidently taken.

SECTION AT SHAFT NO. 1, WHAT CHEER COAL COMPANY.

(Tp. 76 N., R. XIII W., sec. 15, Sw. qr., Nw. ¼.)

		FEET.
4.	Drift	50
3.	Shale, bituminous, fissile	20
2.	Coal	5½
1.	Fire clay (exposed)	4

Numbers 1, 2, and 3, represent the coal measure deposits of the county as characteristically developed.

TYPICAL OUTCROPS.

EXPOSURES ON SOUTH SKUNK RIVER.

SECTION FIVE MILES NORTH OF RICHLAND.

(Tp. 75 N., R. X W., sec. 35.)

		FEET.
4.	Sand, yellow to red, coarse grained, cross-bedded.	8
3.	Limestone, earthy, brown, arenaceous in part; heavy bedded, exposed 6 to	8
2.	Limestone, grey, cherty, fine grained, in twenty inch ledges	6
1.	Unexposed to river	30

Number 3 of the above section may be correlated with number 3 of the Manhattan mill section.

CLEAR CREEK SECTION.

(Tp. 75 N., R. X. W., sec. 27.)

		FEET.
2.	Limestone, in part fine grained, drab, cherty; in part brecciated; interstratified with coarse grained sandstones; (imperfectly exposed)....	10
1.	Unexposed to river....	30

This exposure may be referred to the middle Saint Louis (Verdi beds.) Particularly good examples of the brecciated limestone may be seen at this point.

SAW MILL SECTION.

(Tp. 71 N., R. X W., sec. 6, Nw. qr., Se. ¼.)

		FEET.
1.	Limestone, (Augusta) sub-crystalline, white; an impure marble, rising above the river........	6

Between this section and the one following, the Manhattan mill and Nugent exposures occur. A few hundred feet up the river from the latter is a small ravine which reveals the presence of a coal measure outlier. The bed of black shale which represents the coal measures is deposited in a channel which has been cut down through numbers 4 and 3 of the Nugent section.

SPRINGVALE SECTION.

(Tp 75 N., R. XIII W., sec. 27, Se. qr., Ne. ¼, and sec. 34, Ne. qr.)

		FEET.
3.	Limestone, alternating with sandstone, imperfectly exposed....	30
2.	Limestone, blue, shaly when fresh, weathering readily to earthy brown: exposed near bridge	20
1.	Limestone, coarse, sub-crystalline, fossiliferous...	6

Number 1 of the above is the Augusta. It is seen on the north side of the river some distance from the remainder of the section. Number 2 is the typical exposure of the Springvale beds with the normal thickness, and only unusual in the small amount of arenaceous matter. Number 3 is the middle Saint Louis (Verdi beds), as usual very imperfectly exposed.

The Verdi beds as seen here are well developed along the river from this point to the west county line. At two points

they have been cut through and the coal measure deposits laid down in the cutting. The first of these localities is about one mile west of the section just described. The exposure is very imperfect. About fifteen feet above the water is a thin ledge of bituminous limestone containing *Chonetes mesoloba* and other forms common to the beds of the Des Moines stage.

Within half a mile of the west line of the county the Saint Louis beds are again replaced by sandstones, and in the adjoining portions of Mahaska county by shale containing a small coal seam.

EXPOSURES ON NORTH SKUNK RIVER.

BLACK HAWK MILL SECTION.

(Tp. 75 N., R. X W., sec. 30. Sw. qr.)

At the Black Hawk mill, the Augusta is exposed, showing a thickness of probably twenty feet. It extends down the river nearly a mile, outcropping at intervals along the bluff. It also extends a distance of a mile and a half up the creek, which at this point flows into the river. About one mile north of the mill, the Springvale beds are seen to cover the Augusta.

GERMAN CREEK SECTION.

(Tp. 75 N., R. XI W., sec. 15)

In the bluff back a mile or more from the river there are two exposures of a coarse, reddish sandstone probably of coal measure age.

BRIDGE CREEK SECTION.

(Tp. 75 N., R. XI W., sec. 18. Nw. qr., Nw. ¼.)

		FEET.
1.	Limestone, coarse, grey, fossiliferous	12

This limestone is also exposed in the southeast quarter of the southwest quarter and in the northeast quarter of section nineteen.

SECTION TWO MILES SOUTH OF SIGOURNEY.

(Tp. 75 N., R. XI W., sec. 14, Ne. qr.)

		FEET.
1.	Alternating layers of coarse sandstone and of limestone; the latter in part of a well marked brecciated character, and in part, of the fine grained, compact variety	35

This outcrop is immediately above the wagon bridge south of Sigourney. It represents the Verdi beds, but as usual the exposure is too imperfect to allow the details to be made out.

CEDAR CREEK SECTION.

(Tp. 75 N., R. XII W., sec. 10, Se. qr., Sw. ¼.)

		FEET.
5.	Drift	25
4.	Limestone, thin, shaly	5
3.	Limestone, massive, cherty, slightly bituminous	4
2.	Limestone, arenaceous in places, thin, shaly, not fully exposed	20
1.	Limestone, compact, fine grained	4

These beds may be referred to the upper part of the Verdi.

CONNOR'S QUARRY.

(Tp. 25 N., R. XII W., sec. 15, Se. qr., Sw. ¼.)

		FEET.
2.	Limestone, yellow, soft, magnesian; apparently arenaceous in part, massive; exposed	10
1.	Limestone, coarse, sub-crystalline, exposed at water's edge	4

Number 1 of the above is the Augusta; number 2 belongs to the Springvale beds.

About two and a half miles west of Connor's quarry (Tp. 75 N., R. XII W., sec. 18, Se. qr., Se. ¼), the Augusta limestone, having its usual characterestics rises above the water four feet. Both above and below this point the Saint Louis is well developed.

DELTA SECTION.

Immediately south of Delta is a small group of mines working in an outlier of coal measures cut off in each direction along the stream by Saint Louis. The section passed through in sinking the Martin Fisher shaft (Tp. 75 N., R. XIII W., sec. 14, Ne. qr., Ne. ¼) is as follows:

		FEET.
5.	Drift	4
4.	Shale, bituminous	9
3.	Coal	4¼
2.	Fire clay	4¼
2.	Shale, bituminous	

The mouth of this shaft is 762 feet above sea level and eighty feet above the river. At the mill one mile southwest of

here, there is an exposure of coarse, reddish, heavily cross-bedded sandstone twenty feet thick. This evidently thins before passing below the coal northeast of it.

ATWOOD QUARRY.

(Tp. 75 N., R. XIII W., sec. 8, Ne. qr.)

		FEET.	INCHES.
3.	Sandstone, irregular in thickness	8	
2.	Limestone, fine grained, compact	2	6
1.	Sandstone, coarse, yellow	6	8

This section is measured at the west end of the railroad quarry, the base being 738 feet above sea level. The layers in the quarry are quite irregular, the section measured farther toward the east end of the quarry showing:

		FEET.	INCHES.
5.	Sandstone	2	4
4.	Limestone	1	6
3.	Sandstone 3 to	8	
2.	Limestone, persistent band	2	6
1.	Sandstone, irregular in thickness	15	

The beds at this place belong to the middle Saint Louis (Verdi beds) and probably represent the upper portion of them. They show local disturbances.

EXPOSURES ON ENGLISH RIVER.

Along English river there are but few outcrops of rock. About two miles northwest of Keswick (Tp. 77 N., R. X W., sec. 16) the Augusta limestone at one point rises two feet or more above the water. Two miles north and one east of South English (Tp. 77 N., R. X W., sec. 7, Sw. qr., Sw. ¼) a boring made on the hill shows the presence of coal measures.

SOUTH ENGLISH BORING.

		FEET.
3.	Drift	150
2.	Sandstone, alternating with shale	50
1.	Shale, bituminous	7

Nothing corresponding to this has been found elsewhere in the region, and it is probably merely a small outlier, the more so since the shale lies at a level considerably below that of the surrounding limestone.

KESWICK BORING.

(Tp. 77 N., R. XII W., sec. 32, Sw. qr.)

		FEET.
2.	Drift	100
1.	Limestone, in thin bands, with alternating beds of sandstone	96

This boring was made at the creamery for a well. Number 1 evidently represents the middle Saint Louis which has been encountered in other borings in the vicinity and is at one point poorly exposed on South English river directly north of town.

Geological Formations.

The general sequence of the rocks in the county has already been given. The formations present belong entirely to two systems; the Carboniferous and the Pleistocene. Of the Carboniferous rocks, representatives of both the series most prominently developed in the Mississippi valley occur.

MISSISSIPPIAN SERIES.

The rocks of this series, forming the lowermost of the major divisions of the Carboniferous of the continental interior, underlie the greater portion of the county. Of the three divisions of the series which are found in Iowa—the Kinderhook, Augusta and Saint Louis—the latter two only are present in this county.

AUGUSTA.

The best exposures of the Augusta limestone within this county are near the mouth of Rock creek just north of Ollie. Here the rock is well displayed and is exposed over a considerable area. It is here also that the only serious attempts have so far been made to utilize it as a building stone. The formation rises forty feet above the South Skunk river. The stone varies from light brown or white to grey or drab in color. It is medium to coarse grained, sub-crystalline, and lies in ledges usually three to ten inches in thickness, separated by clay and chert bands. At certain points the latter become especially prominent, as at the Weems quarry (figure 24) near Manhattan mill (Tp. 74 N., R. XI W., sec. 10, Nw. qr., Ne. ¼). The limestone contains an abundant crinoidal and molluscan fauna. Portions of the stone are almost entirely made up of fossils, particularly of crinoid stems.

The distribution of the formation is shown on the accompanying map. There is a small area immediately south of Delta on the South Skunk, another three miles northeast of this on the North river, one near Connor's quarry two miles north of Hayesville, one near the mouth of Bridge creek, the area noticed near Manhattan mill and a small area near the mouth of East Cedar creek in Clear creek township. From the junction of the two branches of Skunk river to the east county line the Augusta does not appear though it probably underlies at least a portion of the bottom land. In the region of Keota borings show that this rock immediately underlies the drift. North of Kinross it is at one point exposed on English river rising scarcely three feet above the water.

Figure 24. Augusta limestone on Rock creek, north of Ollie.

The rocks now known under the name of Augusta have long been known and studied in southeastern Iowa and neighboring regions. They were here considered to make up two formations; the Keokuk, and Burlington. More recently, however,

they have been united and are now known under the name Augusta. It is of interest to note that in Keokuk county there is no evidence of two formations. The rocks mapped as Augusta are markedly distinct from any others occurring in the region and are just as markedly entirely one. The lithological character which distinguishes them in one place is present just as prominently at every other outcrop. The same faunal features are common to all the beds. At a few points only do fossils which have been considered to belong distinctively to the one or the other formation occur. In the main the forms found are more nearly related to the Burlington. The outcrop directly south of Delta, that near the mouth of Bridge creek, and that near the mouth of East Cedar contain certain forms considered as distinctively Keokuk. On the other hand the better developed exposures near Manhattan mill show Burlington forms. Beyond the occasional presence of these few distinctive forms there is no reason for separating the formation. To one not already familiar with the exposures of southeastern Iowa it would never occur that there was any need for such a separation.

SAINT LOUIS.

The rocks which underlie the greater portion of the county belong to the Saint Louis stage. They include both sandstones and limestones, the latter predominating. The sandstones are quite irregular in distribution and ordinarily occur as intercalated beds between limestone bands. The limestone is usually quite fine grained and compact; in places it becomes magnesian, and in other places quite arenaceous. It is this formation which contains the brecciated limestone beds which once gave name to the whole formation.

Springvale beds. Within this county the Saint Louis is seen to be made up of three separate formations, which while not always entirely distinct, are usually well marked. The lower or basal member is well exposed at the old Springvale mill five miles south of Delta on the South Skunk river. As seen here, it is a blue, earthy limestone of a marked shaly character, weathering readily into a soft, brown to buff limestone. It is magnesian and in the other outcrops is frequently arenaceous.

The stone weathers so readily that the blue shaly character is seldom seen. It is, however, the character of the fresh stone found on Rock creek and along the Skunk in Washington and Henry counties. This bed is seen overlying the Augusta at nearly all its outcrops on the Skunk river, though on account of its soft nature good clear exposures are rare. It is exposed in Connor's quarry two and a half miles north of Hayesville (Tp. 75 N., R. XII W., sec. 15), five miles north of Richland (Tp. 75 N., R. X W., sec. 35, Ne. qr.), and may be examined in the J. S. Cook quarry north of Ollie. At this latter place the stone shows a probably pseudo-conglomeratic character. The matrix is the usual soft, brown, earthy mass, within which are imbedded irregular pieces of white limestone and chert such as mark the upper part of the Augusta. It is very suggestive of a basal conglomerate.

Figure 25. Pseudo-conglomerate in Springvale beds, Cook quarry, near Ollie.

The Springvale bed, as this member has been called, preserves its place in the section along both rivers and is usually twenty to twenty-five feet thick. It has so far proven to be largely non-fossiliferous. Its thinness does not give it a large areal exposure and the borings which show the presence of the Saint Louis in the northern part of the county have not been made with sufficient care to settle the question of its presence. At present it is only known along the two branches of the Skunk river where it has been traced across the entire county.

The exact geological position of the bed is open to some doubt. It is very rarely fossiliferous and the forms so far found in it have but slight value as indices of its stratigraphic position

In Van Buren and Lee counties a formation which occupies apparently a similar stratigraphic position and greatly resembles the Springvale beds in lithological character has been traced by Mr. Gordon. It has been usually referred to the Saint Louis though its Warsaw age has also been suggested. So far the Springvale beds have not been directly correlated with those farther south. While there are some reasons for believing that they are homologous with the beds known as the Warsaw, the evidence so far as presented in Keokuk county, tends rather to confirm the idea of their Saint Louis age and to that formation they are provisionally referred.

Verdi beds. The second or middle member of the Saint Louis is that which covers the greater portion of the county. It contains both limestones and sandstones in varying proportions and is the record of a time of exceedingly varied and rapidly changing conditions. Local unconformities are frequently

Figure 26. Local unconformity in Verdi beds, north of Hedrick.

encountered and may be excellently seen north of Hedrick. Thes andstones found are white to orange in color, medium fine in grain and occasionally quite calcareous. They usually occur

in bands from two to six feet in thickness interbedded with the limestone. In some places, however, clean sandstones thirty to forty feet in thickness, with limestone both above and below, are seen.

The limestones are of two different characters. The most usual type is a light ash to buff color, fine grained, exceedingly compact and hard, almost cherty in character. This is the limestone found interbedded with the sandstone. A better known; though not more common type, is that seen in the brecciated beds. In these beds the limestone is broken up into irregular blocks or pebbles and cemented together, the whole forming a distinct calcareous conglomerate or breccia. In a majority of cases the cementing material is calcareous, though this is not always so. In some instances it is a more or less ferruginous sandstone. The blocks or pebbles in the breccia are usually of the fine grained, compact limestone characteristic of the Saint Louis itself and seem to be derived from that formation. Though occasionally slightly rounded, they more usually show sharp angles. They vary in size all the way from a fraction of an inch in diameter to large slabs four feet long and six to eight inches thick. As usually seen, however, the brecciated blocks are from one to two inches in diameter.

The brecciated beds do not seem to occupy a distinct, well marked horizon in the middle Saint Louis but are, in different localities at different levels. At Sigourney they may be seen well toward the top of this member, while along the Skunk river they frequently occupy a medial position. Near the mouth of Clear creek and at Verdi, in Washington county, they are near the base.

The middle Saint Louis in this region shows several well marked facies. The more common is that of the interbedded sandstones and limestones excellently shown at the bridge north of Nugent. This is the facies which borings show to be commonly present under the northern portion of the county. Another facies is that in which the disturbance of conditions during deposition has been so great that there is little or no regularity. This is also well shown north of Hedrick. At this point, near Showman station, on one side of a railway cut, is a

sixteen foot exposure of characteristic brecciated limestone. On the other side is a considerable development of sandstone interbedded with clear limestone.

Another characteristic section of middle Saint Louis is exposed in a railway cut one and a half miles west of Ollie (Tp. 74 N., R. XI W., sec. 32, Nw. qr., Nw. ¼).

		FEET.	INCHES.
7.	Clay soil, reddish, with drift boulders	10	
6.	Sandstone, cross-bedded, lemon yellow to orange, fine grained; becoming harder for six inches and apparently calcareous below	6	
5.	Limestone, compact		8
4.	Marl and limestone		6
3.	Limestone, fine grained, grading below into number 2		4
2.	Limestone, finely brecciated, in places almost oölitic	2	
1.	Limestone, compact, with conchoidal fractures to track	6	

Figure 27. Saint Louis west of Ollie. The prominent heavy bed showing a slight flexure is number 6 of the above section.

The middle Saint Louis is perhaps best shown at the old railroad quarries at Verdi, in Washington county, where nearly all the different facies are presented. For this reason the member has been called the Verdi beds. Its total thickness can not be much less than one hundred feet, as single exposures of more than sixty feet are known.

Towards the close of the period represented by these beds conditions seem to have been more stable, and heavy bedded limestones of considerable thickness began to be deposited. These upper beds are found exposed north and west of Sigourney and have yielded considerable stone.

Pella Beds. The upper member of the Saint Louis of this region is but sparingly present in Keokuk county. It is best seen at Pella, in Marion county, and at the numerous exposures in Mahaska county. It may be characterized as a thick bed of limestone having near the top interbedded calcareous marls. These, as well as the limestone itself, are exceedingly fossiliferous, and indeed it is from this portion of the Saint Louis that almost all the fossils found in it in this region are collected. From their typical exposure these beds have been called the Pella beds. To this division the limestone found south and east of What Cheer, with some of that along the Skunk, may be referred. There is a gradation from the Verdi to the lower Pella beds, and no sharp line can be drawn between them. The latter may be recognized by the absence of the sandstone and the presence of the fossiliferous marls.

UPPER CARBONIFEROUS.

The upper carboniferous overlies the heavy limestones of the Mississippian series conformably in portions of the Mississippi valley, but unconformably in Iowa. The formation is made up in its lower portion of shore deposits which are succeeded by marine deposits which in Kansas, Nebraska and elsewhere apparently merge into the higher beds which are sometimes called the Permo-carboniferous. The Upper Carboniferous is represented in Iowa by two stages, the Des Moines and Missouri, only one of which is present in Keokuk county.

DES MOINES STAGE.

The beds of this terrain constitute what are generally known as the Lower Coal Measures. The distribution of these strata is in this county quite irregular. The main body of the strata extends into the county along the west and south line. In the southwestern part of the county modern erosion has has very seriously limited the area underlain by the beds. Beyond the eastern border of this main body there are many small outliers, a considerable number of which have been mapped. Others are doubtless present, though concealed by drift, and may in time be discovered. Some few of these outliers yield workable coal; most of them do not.

The largest area of coal measures in the county is that found near What Cheer. A boring put down two miles south of What Cheer (Tp. 76 N., R. XIII W., sec. 22, Nw. qr.) showed the following:

	FEET.	INCHES.
6. Drift	147	
5. Shale, bituminous, "slate"	40	
4. Coal	2	2
3. Fire clay	2	
2. Sandstone	3	2
1. Limestone (Saint Louis)		

This section represents well the general order of the strata found in the region; the thickness of course varies greatly and not all these strata are always present. Number 2 is quite rarely found; number 3 may be almost entirely absent, or may become seven or eight feet thick. The coal is usually much thicker; in the mines it generally runs from four to six feet in thickness and is frequently much more. The thickness of the shale (number 5) and of the drift is dependent upon the erosion, preglacial and recent, to which it has been subjected. There is but the one coal horizon in the coal measures here though there is considerable difference in the level at which the coal lies. At the North Star it is 723 feet above sea level while at the Towers mine it is 695 feet. Equally great differences are, however, found in individual mines. The coal itself is very irregularly distributed, though between the levels mentioned it is usually found in greater or less quantity unless erosion has interfered.

It must be remembered, that not only the erosion which has taken place since the deposition of the beds of the Des Moines terrain, is to be considered but also the pre-coal measure erosion. It is due to the latter that in places the Saint Louis is encountered at levels considerably above the neighboring coal beds. At a number of points such conditions exist; hummocks of limestones protruding entirely through the coal measures. The coal itself lies in irregular semi-detached basins. These are usually in the form of troughs with thicker coal in the center thinning out towards the edges. These troughs are generally about 100 yards wide and run in very irregular lines. Some have been traced a distance of a mile or more. A good example of such a coal basin is seen on the land now being developed by the Crescent Coal Company two miles northwest of What Cheer. Here a basin has been located in which the coal is nearly forty-five feet below the general level of the seam on the same land and is from two to three feet thicker.

In the Crescent No. 2, a basin of excellent thick coal was traced some distance in a curved line. It followed close along the edge of a "cut out." In the What Cheer No. 4, a similar basin of coal, in this case in part of an impure or bony character, was encountered. It was in places twelve feet thick, and was exceptional in the thickest part being in some instances far to one side of the center of the basin. This basin has been traced in a parabaloid direction for some distance.

The exceedingly irregular distribution of the coal measures and the influence of the various erosion periods is shown in the following section from east to west through the field.

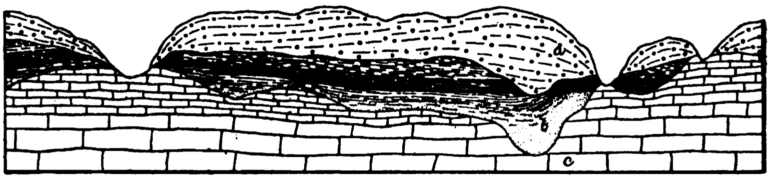


Figure 28. Section through What Cheer coal field.

There is a small Des Moines outlier about four miles east of What Cheer on Smith creek. Several country mines were

opened here ten to twenty years ago, the coal being reached both by shafts and drifts. The coal was from five to seven feet thick and was covered by a good shale roof, but the area is quite small; the Saint Louis beds being exposed ten to twelve feet thick on all sides along Rock and Smith creeks and their tributaries.

Northeast of South English, coal measure strata have been found at a single point as already described.

About three miles north of Sigourney there is a small group of Des Moines outliers which contain considerable coal. There are in all four such areas now known. They do not seem to be connected, and between certain of them at least, there are abundant Saint Louis outcrops. The coal in this field runs from three to four and a half feet in thickness and has usually a fire clay floor and a grey shale roof which is rarely more than twelve feet in thickness. It is usually much thinner and part of the coal must be left for a roof.

Between the old Branner and the Rowley mines there is an outcrop of Saint Louis which has been to some extent quarried. At the base of the quarry is a thin layer, three to four inches thick, of bituminous shale similar in character and on nearly the same level with the shale overlying the coal near by. This same shale has been found at several points in this neighborhood and has led to some confusion. Coal is known to occur at the old Branner mines (Tp. 76 N., R. XII W., sec. 24, Nw. qr., Se. ¼), at the Rowley mine (same section, Sw. qr., Nw. ¼), and at the Wertz mine (sec. 25, Nw. qr., Sw. ¼). In a well near the Rowley mine (sec. 24, Sw. qr., Ne. ¼), shale probably of Des Moines age was encountered.

Four miles east of Sigourney a twenty-two inch seam of coal was at one time worked at the Lockridge mine, but the opening is now abandoned. There is also a small coal measure area directly south of Delta, of which a section has already been given. The exact limits are not well defined, though the area cannot well be a large one. All the coal is taken from the north side of the river in section fourteen. On the opposite side is a sandstone probably of Des Moines age. In section thirteen, the Saint Louis rises in the bluffs a considerable distance

above the coal measure horizon. In the southeast quarter of the same section a small coal measure pocket, probably connected with the Delta area, occurs. It is cut off above and below on the river by the Saint Louis. The exposure shows:

		FEET.
3.	Sandstone, coarse, red; imperfectly exposed	30
2.	Shale, bituminous	4
1.	To river	10

On the South Skunk river west of Springvale mill are coal measure outcrops already mentioned. The one at the west seems to be connected with the main body of coal measures, and a half mile west of the county line a small mine is in operation.

On Steady Run three miles north of Martinsburg (Tp. 74 N., R. XII W., sec. 8, Se. qr., Se. ¼), is a small coal measure outlier from which clay is taken for the manufacture of brick at Martinsburg. An eight inch seam of coal is underlain by fire clay and covered by a drab clay shale. The Saint Louis is exposed at each side in the bluffs of the creek and along its branches.

On German creek, as already mentioned, is a sandstone probably of Des Moines age. Borings on the hills around here show that the Saint Louis immediately underlies the drift so that the sandstone certainly covers only a limited area.

About one mile northeast of the Black Hawk Mill (Tp. 75 N., R. X W., sec. 29, Nw. qr., Ne. ¼), is a small quarry worked intermittently in a red sandstone. The quantity of stone seems to be limited. It lies a few feet above a small stream and a considerable distance above the river. The ledges are now covered by talus and the stone can only be seen in the blocks left on the surface. These show it to be a coarse, ferruginous variety becoming in places conglomeratic. The matrix is composed of quartz grains cemented by ferruginous matter. In this is set pebbles, in part of limestone, in part of quartz, waterworn and resembling river gravel, and in part of worn pieces of chert similar to that found in the Augusta of neighboring outcrops. If indeed that be their origin then we have here either a Saint Louis sandstone laid down upon the Augusta after an erosion interval, or a basal Des Moines

glomerate, which has in itself evidence that the pre-coal measure erosion cut entirely through the Saint Louis and exposed the Augusta. The evidence seems to favor the latter view. No fossils occur in the deposit. Two miles northeast of here, or a mile west of Tallyrand, is an exposure of sandstone very similar in character, though the conglomeratic facies seem absent. At this point there is, in connection with the sandstone, a body of bituminous shale which is similar in character to the usual coal measure shale, hardly admitting a doubt that the deposit is of that age.

South and west of Richland is a Des Moines area apparently connected with the coal measures of Jefferson county. The coal lies at a depth of about eighty feet under the uplands. The greater portion of the covering is drift, only a few feet of light shale being found over the coal. A section of the strata at the Smith mine (Tp. 74 N., R. X W., sec. 3, Se. qr., Se. $\frac{1}{4}$), is fairly representative:

		Feet.
6.	Clay, yellow	10
5.	Clay, blue, with boulders	20
4.	Clay, fine, light colored	40
3.	Shale, light grey	6
2.	Coal	4
1.	Fire clay	

The coal here is quite irregularly distributed, in places being entirely absent. It is mined now along the south fork of Richland creek. At one time coal was taken out directly west of Richland, though this opening has long been abandoned.

PLEISTOCENE.

The deposits which cover the greater portion of the county belong to the Pleistocene period. They consist of till, gravel, sand, clay, loess and alluvium. In thickness the beds are usually from 100 to 125 feet, though in the northern part of the county it reaches a probable maximum of 200 feet over the uplands, while individual borings show occasionally slightly greater depths.

DRIFT.

As seen along the streams and in well sections the most usual material is glacial till, consisting of a fine yellow clay

through which is disseminated the smaller sizes of gravel. Boulders are frequently encountered and are of all sizes and materials. Below this yellow boulder clay a blue variety is frequently encountered but has not as yet been traced from point to point. Gravel beds are infrequent and of small extent. Sands are also comparatively rare in any quantity. Directly north of Keswick two semi-detached hills of stratified sand are found at the edge of the bluffs.

LOESS.

Over the uplands is usually a thin covering of a loess-like deposit which never becomes prominent. Genetically related to it, being indeed probably merely an altered form of the loess, is a bed of stiff blue-grey to yellow clay, usually free from gravel and lime. This covers the whole of the upland south of the South Skunk river and also the piece of level land lying between Harper and Keota. Indeed it is not rare in any part of the county where there is level land. An important clay industry has been founded upon it.

ALLUVIUM.

The broad bottoms of the Skunk rivers and the narrow lowlands along the various other streams are made up of alluvium. This is a black loamy soil derived from the washing of the hills. It is from fifteen to twenty feet thick over the larger bottoms and in the minor valleys from two to eight feet deep. Along the smaller streams it is frequently cut through showing the glacial clay below, while on the larger bottom lands, the alluvium usually entirely conceals the drift, the latter showing along the streams only at intervals. This difference is probably due to the present relatively more rapid action of the side streams.

Geological Structure.

CROSS SECTIONS.

North Skunk Section. (Figure 1, plate viii.) Near the mouth of the North Skunk, the Augusta begins to appear from beneath the water. At Black Hawk mill it has risen to twenty feet or more, and the Saint Louis is seen above it. Beyond here an old

channel of German creek makes outcrops rare. A sandstone of Des Moines age is seen at one point, and well records show the hills to be made up of Saint Louis. At the mouth of Bridge creek there are several exposures of Augusta, the Springvale and Verdi rising over them. South of Sigourney the Springvale beds are prominent. About four miles west of here the Augusta is again exposed, both the Verdi and Springvale being also seen. South of Delta is the coal measure area already described, while from Delta west to Atwood the Verdi beds are frequently seen along the railroad.

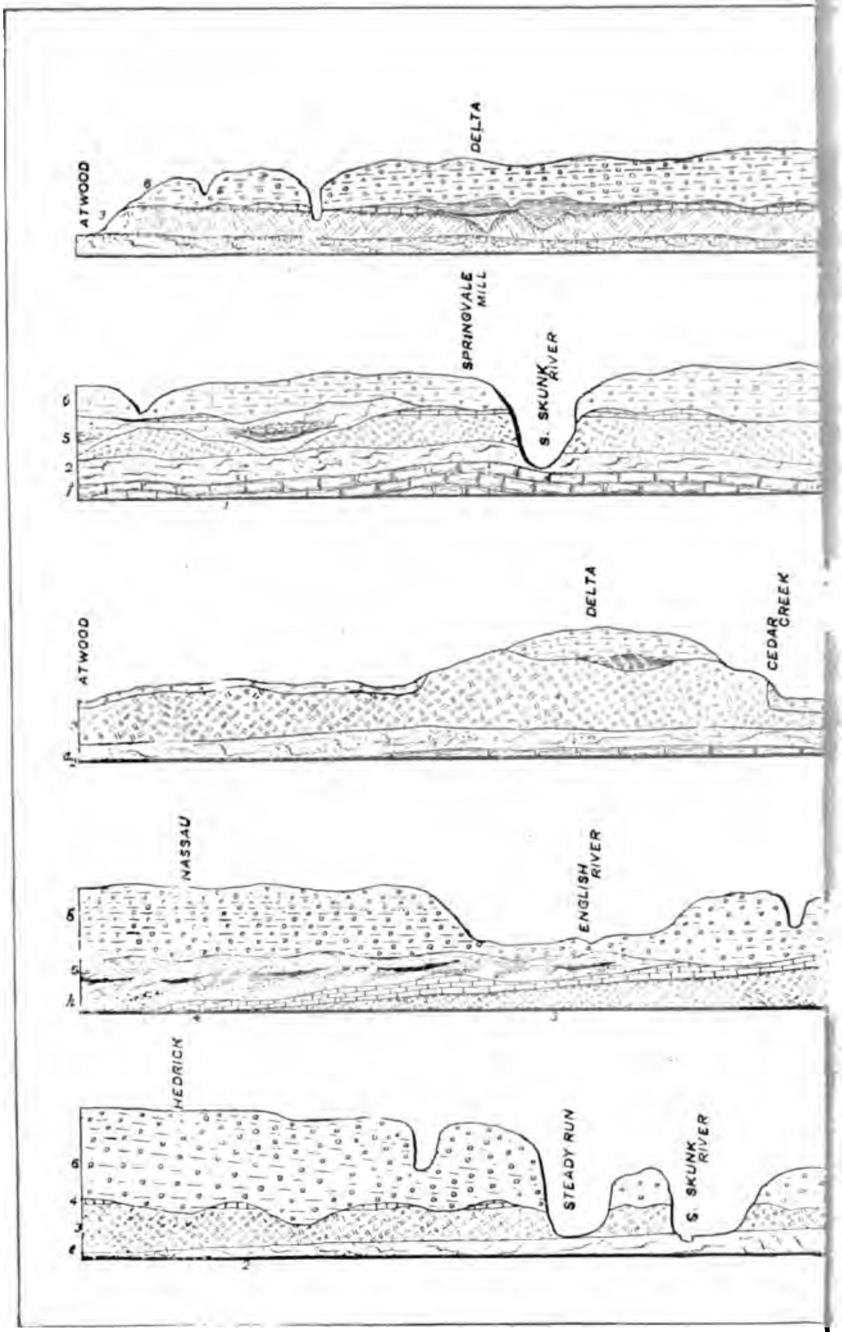
South Skunk Section. (Figure 2, plate viii.) In Washington county near the west county line there is an outcrop on the Skunk river which shows the Springvale beds at the edge of the water with part of their thickness apparently below that level. When the county line is crossed westward, broad botton lands are encountered. The Saint Louis is imperfectly exposed in the bluffs some distance from the river. The Verdi beds and the upper portion of the Springvale beds are seen. Their height above the water indicates that the river level must have cut down close to the Augusta, though no rocks of this formation are seen more than a few miles below Manhattan mill. At the latter point they rise forty feet above the water, the Springvale and Verdi beds running up over them, the latter somewhat reduced in thickness. West of this point the Springvale beds come down towards the river, the Verdi beds regaining their usual thickness of forty to sixty feet. At the bridge north of Nugent the Springvale beds are partly below the water. Immediately west of here shales of the Des Moines terrain appear in a gorge cut down nearly through the Verdi. North of Hedrick the Verdi and Springvale beds are well exposed along the river, the former being especially prominent. On the north side of the river at the old Springvale mill the Augusta rises above the river, while at the bridge the Springvale beds have their typical exposure. This is the last point on the river at which their full thickness is shown. West of here they may be seen at a few points near the water. The bluffs are, however, made up largely of Verdi strata which are here particularly arenaceous.

They have been cut into largely and coal measures are frequently seen overlying them.

Section, Keota to Atwood. (Figure 3, plate viii.) At Keota the Augusta limestone is covered by about sixty feet of drift. Between that point and Sigourney there are no outcrops along the railway. It seems probable that the Saint Louis extends as far east as Harper with probable outliers beyond. Four miles east of Sigourney there is a very small coal measure outlier. Sigourney itself is built on the Saint Louis, the upper part of the Verdi outcropping just west of the town. Between Sigourney and Delta the Saint Louis outcrops along Cedar creek, and from Delta to Atwood it is again prominent.

South English River Section. (Figure 4, plate viii.) Over the northern portion of the county the drift is thick and outcrops are rare. In the northwestern corner of Washington county is a deep gorge cutting apparently entirely through the Augusta and into the Kinderhook. This is filled in with drift and crossed nearly at right angles by the present river. This old river valley probably extends into Keokuk county a short distance. About three miles west of the county line and north of Kinross, the Augusta outcrops along the river. North of South English coal measures occupy a pocket in the Augusta, and at Webster the Saint Louis underlies the drift. The Des Moines beds apparently do not extend beyond the eastern line of Prairie township. Throughout the greater portion of the township they apparently underlie the drift, being entirely absent only exceptionally.

North English to Hedrick. From North English to Webster the drift seems to directly overlie the Saint Louis. At the latter point it is particularly heavy as it is here that the watershed between the drainage system of the English and Skunk rivers is crossed. At Rowleys mine is a small coal measure outlier. At Sigourney the drift overlies the Saint Louis which is exposed north of town on Bridge creek and south on both the branches of the Skunk river. At Hedrick the greater elevation seems to be due to an increased thickness of drift rather than to the presence of any coal measures.


ATWOOD
DELTA
SPRINGVALE MILL
S. SKUNK RIVER
ATWOOD
DELTA
CEDAR CREEK
NASSAU
ENGLISH RIVER
HEDRICK
STEADY RUN
S. SKUNK RIVER

EXPLANATION OF PLATE.

In Plate viii are represented the cross-sections described above. The numbers refer to the formations as follows: (1) Augusta, (2) Springvale, (3) Verdi, (4) Pella, (5) Des Moines, (6) Drift.

DEFORMATIONS.

The geological structure of Keokuk county is comparatively simple. As usual the rocks have a slight general dip to the southwest, the strike running nearly at right angles. The latter has been greatly modified by erosion and in the case of the Des Moines beds the present strike is exceedingly irregular.

The record of disturbance since the deposition of the strata is but slight. Two well marked though slight anticlinals have been determined with the probability of a third between the two. The first of these may be called the Manhattan anticlinal since the Manhattan mill is located nearly upon its crest. Its height is forty feet, and its direction is almost exactly northeast. The north branch of Skunk river crosses it at the Black Hawk mill.

The second anticlinal runs parallel with this and is crossed by the South Skunk at the old Springvale mill. The North Skunk crosses it about five miles southwest of Sigourney, and the South English seems to cross it about two miles north of Keswick. At this point is the only exposure of Augusta limestone found on South English in this county. The three outcrops are on a direct line. Midway between these two anticlinals at the mouth of Bridge creek on North river the Augusta rises above the water. No corresponding exposures are seen on South Skunk, though it must be admitted that the locality is unfavorable for outcrops.

In tracing these deformations very little help can be obtained from either the Saint Louis or the Des Moines beds, and results must be based almost entirely upon the Augusta. The coal measures and the Saint Louis limestone have both been so profoundly eroded that inferences drawn from the elevation of different outcrops, or the present distribution of the rocks is of small value. In the Saint Louis of this region there seems to

be no certain line of division above the base of the Verdi. The Springvale beds are constant in thickness and character, and thus are of considerable value for purposes of stratigraphy. They, however, immediately overlie the Augusta and follow the irregularities of its surface so that in the end it is the outcrop of the Augusta which allows the structure to be determined.

Skunk River Anticline. McGee in his monograph on the Pleistocene history of northeastern Iowa has described several deformations in the strata of the state*. These are approximately parallel and trend northwest to southeast. One of these has been called the Skunk river anticlinal and of this he says:

"(10) A parallel anticlinal brings the St. Louis limestone to the surface in the valley of Skunk river for many miles, probably from Ames, in Story county, to the southern part of Keokuk county; and still farther southeastward it finds expression in the exceptionally high altitude of the subcarboniferous rocks in western Henry county."

The appearance of the Saint Louis along the narrow line, as shown in the maps before published, was indeed striking. Recent work, however, has led to the belief that this is due, not so much to an anticlinal, as to the work of erosion. This appearance largely disappears on the new map of Keokuk county and is greatly changed on that of Mahaska county. For the reasons just given any determinations of structure must be based upon the base and not the top of the Saint Louis. It must be remembered that the effect of erosion on the latter has been such that differences of sixty feet in elevation in as many yards are not unusual. Another fact of importance in this connection is the extreme thinness of the coal measures which renders them easily cut through by erosion and so exposes the underlying limestone along the streams. The deep mines in both Keokuk and Mahaska counties are invariably upon the uplands, and the greater thickness of strata passed through is usually made up of drift. Numerous connected levels show that the coal lies along the same general

* Eleventh Ann. Rep. U. S. Geol. Sur., pp. 338-347. Washington. 1893.

horizon and that the Saint Louis rarely shows any irregularities which cannot be amply accounted for by the erosion it has suffered. The few deformations which have been definitely located run almost at right angles to the Skunk river anticlinal.

UNCONFORMITIES.

There are two great unconformities which have exerted a marked influence upon the distribution of the formations.

UNCONFORMITY BELOW THE DRIFT.

The widespread unconformity between the indurated and recent rocks has left its marks here as elsewhere. In this county the period of erosion marked by this unconformity has had an important economic effect in the removal of the greater portion of the coal deposits which once doubtless covered the whole county. So profound has the erosion been that over the greater portion of the area only scattered outliers, remnants of the once thick sheet of coal measure strata are left. These are of very irregular distribution so far as now located. Doubtless others are concealed beneath the drift.

The older rocks better resisted this erosion yet they too show its profound effects. In Poweshiek county just north, and in Washington county east, traces of an old drainage system have been found. At one point near Deep River a gorge has been cut in the limestone 250 feet deep. Apparently this same gorge just touches the northeast corner of Keokuk county. This older drainage system was apparently blocked up and buried some time during the glacial period, and so far as Keokuk county is concerned it does not seem to have influenced the modern river system.

UNCONFORMITY BELOW THE COAL MEASURES.

That the coal measures in this state rest unconformably upon the underlying rocks has long been recognized, and the relations between the two formations have been discussed by many workers till now the nature of the unconformity and many of its details are well understood. In brief it may be said that the time represented by the Kaskaskia deposits farther south was in Iowa a period of erosion rather than of deposition;

and that the Des Moines beds rest directly upon the Saint Louis limestone.

At the close of the Saint Louis epoch there was a period of elevation. The sea retreated and Iowa became an area of dry land, remaining so until the opening of the Upper Carboniferous. During the intervening period the land was exposed to erosive agencies and the old Saint Louis surface was given a topography not greatly unlike that of the present surface. The streams of that period carved their way down through the level strata to a depth in many cases exceeding a hundred feet. The hills on either side rose with quite precipitous slopes. Deep valleys and level-topped plateaus, narrow gorges and sharp ridges were all engraved on the face of the newly made limestone.

It was upon such a surface as this that the coal measure deposits were laid down and its irregularities profoundly influenced their distribution. These old hills served not only to limit the individual beds, but often directly conditioned their deposition. Whether at any point a coal bed was deposited depended very largely on whether the coast line was high, steep and forbidding, or whether it was low, retreating and fitted for the formation of coal swamps. It seems probable that the exceedingly irregular distribution of the coal along the basal coal horizon may be largely due to this factor.

The length of time that the land was exposed to erosion cannot even be approximately estimated. In this county there are a few facts bearing on the question. It seems probable, from the sandstone exposed at and near Talleyrand as described above, that the interval was sufficiently prolonged to allow the entire Saint Louis to be cut through. In Keokuk and Mahaska counties there are exposures showing about one hundred and fifty feet of strata which may be referred to the Saint Louis. How much has been removed from above that cannot be said. Over the greater portion of Keokuk county the Saint Louis beds which remain are less than 100 feet thick, and at many points were apparently not more than that when covered by coal measures.

Near Tioga, in Mahaska county, and running down into Keokuk county, is a coal measure outlier which rests upon the Verdi beds apparently near their base. At Nugent shales of the same age have been deposited in a channel in the Saint Louis which was cut down to within a few feet of the top of the Springvale beds.

ECONOMIC PRODUCTS.

COAL.

Keokuk county lies well toward the eastern margin of the Iowa coal field and consequently the coal measure strata covering it are comparatively thin. For reasons already explained, the Des Moines terrain does not spread over it in an even bed but occupies rather a series of detached areas. It does not seem probable that in this county the coal measure strata underlie much more than seventy-five square miles of territory. Nevertheless the county has for some years ranked among the more important coal producing districts of the State.

As has already been shown the conditions at the opening of Des Moines time were exceedingly favorable for the formation of coal. Hence the basal portion of this formation is especially productive. It is just this portion which erosion has left undisturbed, and so it happens that while the area is small it has been a very large producer. There are now in the county four regions in which coal is being mined. These are the What Cheer, Delta, Richland and Sigourney districts.

WHAT CHEER DISTRICT.

This is not only the largest producing region in the county, but has been and is yet one of the more important coal districts of the State. Of recent years the production has fallen off considerably and the impression has gained ground that the field is worked out.

In and around What Cheer there are about fifty square miles which are underlain by coal measures. What portion of this area contains coal can not be definitely stated. Drilling has shown that a considerable part contains no coal and that some contains coal which is unavailable for large mining

operations, either because of the thinness or irregularity of the vein, or the absence or poor quality of the roof. A considerable portion of the coal will undoubtedly be ultimately mined for local purposes by smaller mines.

Up to the present time only about twelve square miles of territory have been thoroughly mined out. Some of the region has never been prospected in any adequate manner, and during the present year a new mine has been opened in coal running from four to seven feet in thickness on land which had once been prospected and declared valueless. Recently considerable bodies of coal have been located and several new mines have been opened so that the prospect of the camp seems now quite good.

There is here but the one coal horizon and the irregular distribution of the coal along that horizon has already been mentioned. The coal found is of good quality and is in steady demand for steaming purposes.

The conditions of deposition, as exemplified at What Cheer, are characteristic of the Des Moines beds. The considerable amount of prospecting and mining done here has made them better understood than elsewhere. The old limestone hills are seen to protrude through the coal measures which were laid down around them. The slow currents charged with fine impurities have left their record in the ridges of bony coal,

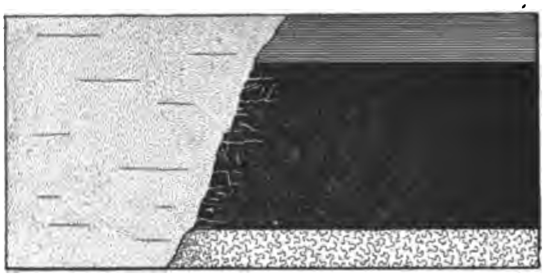


Figure 29 Cutout in What Cheer No. 5.

and the action of swifter currents cutting out the new-formed beds and depositing in their place sand and other material is seen in the various forms of "cut outs." One of these gullys, probably of later origin, now filled with sand and shale,

has been noted in theWhat Cheer No. 5. It is represented in figure 29, in which the coal is cut off abruptly and the space occupied by sand. The face of the coal in contact with the sand is badly weathered for a distance of several inches. The following is the section of the coal seam:

		FEET.
3.	Shale, black, fine grained, fissile	2
2.	Coal	6½
1.	Fire clay, fine, grey	½

In the process of consolidation by which the soft, woody tissues were transformed into coal, there was considerable settling. This has given rise to a large number of true faults which, however, are of insignificant throw and seem to have no relation to any general movement. This settling may also have caused certain of the "rolls" and "horse-backs" encountered at numerous points. The basins already described seem in places to owe their form in part to this readjustment. In general, however, the preexistent topography was probably their determining cause.

What Cheer Mines.

NAME.	Township.	Range.	Section.	Quarter.	¼	Elevation.	Depth.	Thickness of Coal.
What Cheer No. 1	76	XIII	15	NE	NE	------	70	5½
What Cheer No. 2	76	XIII	5	SW	SW	839	120	-----
What Cheer No. 3	76	XIII	3	NW	SE	------	125	4
What Cheer No. 4	76	XIII	3	SE	NW	------	135	5
What Cheer No. 5	77	XIII	34	SW	SE	852	117	6
North Star	77	XIII	34	SE	NW	828	105	-----
Broomhall H	77	XIII	34	SE	SW	818	125	-----
Rosetta	76	XIII	4	SE	NW	787	70	-----
Muscatine	76	XIII	5	NE	SE	792	80	-----
Morgan	76	XIII	4	SW	SW	------	Slope	-----
Keystone No. 1	76	XIII	9	NE	NW	------	------	-----
Keystone No. 2	76	XIII	9	NW	NE	------	Slope	-----
Star F	76	XIII	10	NW	SE	------	------	-----
Tower & Co	76	XIII	10	SE	SW	748	53	-----
Thomas Brothers	78	XIII	10	SW	SE	728	33	-----
Moline	76	XIII	10	SW	SW	------	------	-----
Thompson	76	XIII	10	NW	NE	------	44	6
Armstrong	76	XIII	15	NE	NW	766	44	6
Thos. Armstrong	76	XIII	10	NE	SW	------	------	-----

What Cheer Mines—Continued.

NAME.	Township.	Range.	Section.	Quarter.	¼	Elevation.	Depth.	Thickness of Coal.
Crescent No. 1	76	XIII	4	NW	SE	820	72	5–7
Crescent No. 2	76	XIII	33	SW	SE	826	104	5–6
Crescent No. 3	76	XIII	5	NW	......	845	125	....
Blankquart	77	XIII	32	SE	SE	......	Slope	.....
Black Diamond	76	XIII	9	SE	SW	......	33	6
Shaft B	76	XIII	4	SE	NW	......	......	....
Pioneer No. 1	77	XIII	27	NE	NW	......	Slope	....
Pioneer No. 2	77	XIII	22	SE	SE	......	93	6
Starr A	76	XIII	9	NE	NE	879	....	....

The principal operations in this district have been carried on by the What Cheer Coal Company. This company acquired control of several of the larger earlier mines and after they were worked out opened up five large mines of their own. Two of these, Nos. 2 and 3, have been abandoned for some time, while No. 1 has only recently ceased to operate. Nos. 4 and 5 are nearly worked out and the company is preparing to open up new territory northeast of town where a considerable body of coal has recently been located.

Another of the larger mining companies of the district is the Crescent Coal Company. The two mines operated by it for some years past, the Vulcan and the Cory, have lately been abandoned. The plant is being removed to the new territory recently developed by the company northwest of town where mine No. 3 is now being opened. One of the borings put down at this point showed:

	FEET.	INCHES.
3. Drift	107	9
2. Shale, bituminous "slate"	19	
1. Coal	7	6

There is, as usual, considerable variation in the thickness of the different strata. The coal runs from three and one-half to seven and one-half feet in thickness and seems to be covered over most of the field by a good thickness of "slate."

The North Star mine has been operated by various firms for some years, supplying considerable coal for the local trade. Recently this, with considerable adjoining property, has passed into new hands. The new company is preparing to develop the property and work it as a shipping mine. A number of borings have been put down, and a well protected seam of coal, running from three to six feet in thickness, and lying about 723 feet above sea level, has been located. A representative boring on the property is as follows:

		FEET.
3.	Drift	100
2.	Shale, bituminous	23
1.	Coal	5½

The Thomas Brothers mine is a slope opened in 1893. The firm loads coal on the Burlington, Cedar Rapids & Northern railway, and also supplies considerable for the local trade. The coal lies at an elevation of 695 feet. Towers & Co. reach the same bed of coal by means of a shaft a short distance east of the Thomas slope. They also ship on the Burlington, Cedar Rapids & Northern railway.

The Morgan, Black Diamond and Thomas Armstrong are all small mines worked mainly for the local trade.

The Pioneer Coal Company is located just south of Thornburg. The original mine was a small slope operated for local trade. Later, No. 2 a shaft mine, was opened north of here and the slope abandoned. The mine is now working and considerable coal is being taken from it.

DELTA DISTRICT.

The Delta area lies about six miles south of What Cheer and the two districts do not seem to be connected. Coal has been taken from several shafts and slopes all located within a short distance of each other. At present only two mines are being worked. The Martin Fisher mine (Tp. 75 N., R. XIII W., sec. 14, Ne. qr., Ne. ¼) is a shaft fifty-five feet deep, the coal being about 712 feet above sea level. The Charles Olive mine is a slope reaching the same bed of coal (Tp. 75 N., R. XIII W., sec. 14, Ne. qr., Se. ¼). The vein runs from four to five and one-half

feet in thickness and is of an excellent quality. The quantity seems to be quite limited.

RICHLAND DISTRICT.

In the Richland district, as has been explained, the coal is but poorly protected; the roof is thin shale and hence only small mines can be opened. There is, accordingly, a large number of deserted shafts, only two mines being now in operation. The Smith mine is about four miles southwest of Richland (Tp. 74 N., R. XIII W., sec. 31, Ne. qr., Se. ¼). The coal averages four feet in thickness. The roof is a gray clay shale from six to ten feet thick and requires considerable timbering. The section seen in the mine is:

		FEET.	INCHES.
4.	Shale, light grey	2	
3.	Coal, impure, shaly		2
2.	Coal, without partings	4	
1.	Fire clay, soft, white to grey	2	

The coal is more or less undulatory and shows in places step faults with a total displacement of six feet or more. A few clay seams and one or two "pinch outs" have been met with. The latter are in no case of great extent. Near this mine is a number of deserted shafts. It is customary, in this field, to work only a small area from each shaft, and when any difficulty is encountered the mine is abandoned and a new one opened. In this way as many as five shafts have been sunk on a forty acre tract.

About one mile east of the Smith mine is the Cordis mine, which is on a branch of Richland creek. This mine works in coal similar to that at the Smith mine, and it probably belongs to the same coal horizon. The roof here is of the same character and the coal from three to four feet thick. The fire clay under the coal is said to be fifteen feet in thickness. In the vicinity are also many abandoned mines.

SIGOURNEY DISTRICT.

The Sigourney region has already been quite fully described. There are now only two mines in operation here. The Rowley mine (Tp. 76 N., R. XIII W., sec. 24, Sw. qr., Ne. ¼) and the

Wertz mine (sec. 25, Nw. qr., Sw. ¼). The coal in each is from three to four feet in thickness and has usually a very poor roof, it being necessary in some places to leave part of the coal to protect it. At the Rowley mine the following section was taken.

		FEET.
3.	Shale, black fissile	1
2.	Coal, no partings	3½
1.	Fire clay (exposed)	1

The old Branner mines, in which the coal was reached by drift, was located immediately north of Rowley's mine (sec. 24, Nw. qr., Se. ¼).

CLAYS.

CHARACTER AND DISTRIBUTION.

There are within the limits of this county three series of clays which are available for manufacturing purposes; alluvial, drift and coal measure. Along both branches of the Skunk river, and to a considerable extent along their tributaries, as also along the South English and its tributaries, the first of these formations is well developed. The Skunk river bottoms are usually from two to four miles wide, this bottom land representing the flood plain of the river. This plain is covered with an alluvial deposit of fine homogeneous black earthy soil, varying in thickness up to twelve and fifteen feet. A very considerable portion of this is of a grade not in the least inferior to alluvial matter elsewhere worked up into the rougher grades of clay wares. There seems no good reason to doubt that it could also be used, though no such attempts have so far been made.

The drift supplies the greater portion of the clays at present used. A very considerable portion of the drift here, as elsewhere, consists of yellow and blue clays, throughout which are scattered pebbles and boulders. At a number of places this clay is found in beds of considerable extent quite free from gravel. This seems to be more especially true upon the highlands where the upper portions of the clay beds are found. It is this portion which supplies the major number of brick and

tile factories of the region. The clay usually varies from yellow through grey or drab to blue in color, and, while having numerous local characteristics, is, in the main, a quite plastic, easily worked clay wherever found. It burns to a good color and does not, as a rule, check badly in drying if reasonable care be used. It is especially valuable as a tile clay. It seems to be a deposit closely akin to the loess and probably genetically related to it. Very likely it is but a phase of that deposit, though differing from it in its plasticity, color and density.

The coal measure clays and shales which are well developed over a portion of the county, are not as yet extensively utilized. At What Cheer, Thornburg, Sigourney and Delta, and also near Richland and Martinsburg, are clays which might be used to advantage. The Des Moines beds of this region contain but one coal horizon. Below the coal found along this horizon is the usual bed of fire clay, while above is a bed of clay shale of varying thickness.

Besides being excellent for common brick and tile it is probable that the shale would work up into good paving brick. Practical tests have shown that the fire clay is, at most points, of excellent quality and well adapted to numerous uses. Increased use, and consequently increased value of the clay beds, may safely be expected in the not distant future.

CLAY INDUSTRIES.

What Cheer. Wilson Brothers and Company operate a large brick and tile factory in the southern part of What Cheer on the Chicago & Northwestern railway. On the premises is an old mine from which it is intended to take fire clay. At present the drift or loessal clays alone are used. These are found on the premises and here contain a little gravel which is avoided as much as possible in mining. The clay is run through a Hoosier disintegrater and moulded on a No. 3 Brewer machine. Some of the ware is dried under sheds, but the greater portion is run on tracks direct from the machine into a furnace-heated brick dry-house 20x102 feet in size, where it is kept about fifty hours and then carried on the same truck to the kilns to burn. Three down drafts and one cased kiln are used in burning.

Bolton Brothers operate a brick yard in the northern part of What Cheer. The clay used belongs to the loess formation and is of good quality, free from gravel. One horse power Chief brick machine is used, and the ware, common brick, is dried for two weeks under open sheds. The bricks are burned in cased kilns, and are of a dark red color. The main portion of the output goes to an important local trade.

South English. Lawler Brothers' brick and tile factory is located in the southern portion of South English. Two different Pleistocene clays are used. One is a dark blue clay of exceptional strength which is used for the larger sizes of tile. The principal output, however, consists of brick and the smaller sizes of tile which are made from a yellow to gray loessal clay found near the factory. This is quite free from gravel or other foreign matter. It is spaded and carted to the mill where it is re-spaded and tempered. The supply for one day is prepared usually the day before. The ware is moulded on a McKenzie brick and tile machine and dried under closed sheds heated by steam pipes, where it dries in about one week's time. Three down draft kilns are used in burning.

Delta. Mr. E. Whistler formerly operated a plant immediately north of Delta. The usual drift clay was used, being prepared one afternoon for use the next morning. One F. Clarke brick machine was used. The brick were dried in a closed shed and burned in cased kilns. The output consisted entirely of building brick consumed locally. Since 1893 this plant has not been in operation.

Sigourney. J. S. White owns a brick and tile plant located two miles south of Sigourney on the Chicago, Milwaukee & Saint Paul railway. The usual loessal clay is here of a yellow color and about fifteen feet is taken. The clay is moulded as a stiff mud on a Brewer machine, and dried in closed sheds. In burning two cased kilns are employed, and wood is used for the fuel. Building brick and the smaller sizes of drain tile form the main output, though a few sidewalk blocks have been made. The trade is largely local.

Hedrick. F. W. Heidenreich operates a tile factory in the northern part of Hedrick. An altered loess of gray to yellow

color, occurring twelve feet thick, is used. It is moulded on a Brewer machine and dried in closed sheds. All sizes of tile from two and one-half to ten inches are made, but no brick has been turned out for two years. The clay used for tile is too strong for brick, and they were made of the top dirt. The ware is water-smoked with wood and then burned with coal.

Martinsburg. The Harbey & Gaston brick and tile works are located just west of Martinsburg on the Iowa Central railway. At this place both altered loess and coal measure clays have been used. The former is of the usual gray to yellow variety and is here quite clean. The fire clay is obtained from a small coal measure outlier two miles north of town on Steady Run. At present the main output of the factory is tile, which is mainly four-inch, though some threes and larger sizes are made. These are made of the loess clay alone. The bricks are made of two-thirds loess clay and one-third fire clay, the combination producing an excellent building brick. The fire clay was tried alone, and, while it makes a fine building brick, it is here not sufficiently pure for a good grade of fire brick. The clay is moulded on a Brewer machine. The ware is dried in closed sheds and does not usually check badly. In hot weather there is some trouble, but it is obviated by covering the more exposed parts with canvas. Two down drafts are used in burning.

Richland. Orvil Draper owns a brick and tile factory in the southwestern part of Richland. A loess clay, here fifteen feet thick, is used. The ware is moulded on a Brewer machine and dried under closed sheds, and afterward burned with wood in cased kilns. Brick forms the main output, though some tile, mainly fours and fives with a few threes and eights, are made. The trade is largely local.

Keota. Clarke & Leacox at Keota use an altered loess clay similar in character to that used elsewhere in the county. It is moulded on a Bennett side delivery brick and tile machine and dried under closed sheds. The clay here checks even worse than usual, and extreme care is necessary in drying. Tile dry in from two to three weeks, while brick requires about a week

longer. The clay burns to a good color, three down draft kilns being used.

BUILDING STONES.

All the indurated rocks exposed within the limits of this county have at some time been more or less quarried. Nearly every portion of the county contains an abundant supply of rock for all local purposes, and at a few points stone of an excellent quality occurs in quantities sufficient to warrant shipping.

DES MOINES.

The coal measures here yield but little stone. At one or two points a sandstone referable to that age outcrops. It is usually too soft and incoherent to be of any value. At the mill on the North Skunk river, two miles south of Delta, there is a heavy, red to yellow sandstone which has been used to some extent about the mill, mainly in the construction of the dam.

SAINT LOUIS.

Of the Saint Louis formation, which covers the greater portion of the county, the upper or Pella beds furnish the best stone. The stone is of the compact, fine grained variety, usually of a drab color, and lies in ledges eight to eighteen inches in thickness. In the region southeast of What Cheer, it is exposed along the various streams usually to a height of seven to twelve feet. It has been opened up here at a number of points, the quarries all showing stone of the same general character. The stone is used for local trade and the output varies greatly from year to year. The greater portion is used for foundation stones and well curbing.

At the quarry of Terry Lotscher, two miles east of What Cheer (Tp. 76 N., R. XIII W., sec. 11, Se. qr., Se. ¼) the surface of the stone has an elevation of 730 feet, rising ten feet above the bed of Rock creek. On Smith creek, two miles east, stone is also quarried at about the same level. The rock quarried north of Sigourney belongs in part to this division and in part to the upper portion of the Verdi; the two grading into each other. The section at the Rowley quarry (Tp. 76 N., R. XIII W., sec. 24, Nw. qr., Se. ¼) is:

		Feet.
5.	Clay, yellow, with boulders	12
4.	Limestone, in thin, 2-inch layers	4
3.	Limestone, solid ledge	1
2.	Limestone	2
1.	Shale, black	½

In ledge No. 4 *Rhynchonella ottumwa* White, and other Saint Louis forms occur. This quarry supplies considerable stone for local purposes. Stone has also been quarried a short distance west of here (sec. 23, Ne. qr., Ne. ¼). This quarry is not now in operation though considerable rock has apparently been taken from it. Stone has also been quarried northwest of Sigourney (Tp. 76 N., R. XII W., sec. 34, Nw. qr., Ne. ¼) and (Tp. 75 N., R. XII W., sec. 2, Nw. qr., Sw. ¼). These quarries work stone belonging to the Verdi beds, the sandy member as also the brecciated limestone being present.

The Verdi beds have been opened up at a number of points, usually for obtaining stone for immediate purposes, as north of Nugent (Tp. 74 N., R. XIII W., sec. 12, Nw. qr., Ne. ¼) where stone was taken out for the piers of a neighboring bridge.

The Verdi does not furnish as much good stone as the Pella beds, since the brecciated and soft sandy members form so considerable a portion of the whole formation. The Verdi was at one time quite extensively quarried by the Chicago, Rock Island & Pacific railroad a mile east of Atwood, the stone being used to some extent for bridgework, but mainly for ballast. The very irregular character of the ledges and the softness of the sandy members caused the effort to be abandoned.

The Springvale beds yield some stone. At the typical locality stone from this formation has been used in dam work. North of Hayesville at Connor's quarry (Tp. 75 N., R. XII W., sec. 15, Se. qr., Sw. ¼) it is also worked slightly. The stone here is in part a soft yellow, earthy limestone and in part a sandstone. The latter is the more prominent facies in a small quarry north of Richland (Tp. 75 N., R. X W., sec. 35). At the Cook quarry north of Ollie the Springvale must be stripped off to reach the Augusta. It is, however, too soft to be of any value.

AUGUSTA.

The best quarry stone occurring in the county is found in the Augusta formation. This is a hard sub-crystalline limestone occurring in buff, blue and white colors. It runs in even ledges of good workable thickness. It is easily dressed and stands exposure excellently. Polished specimens show that it is well adapted to certain kinds of monumental and interior work.

While the area occupied by the Augusta is in this county quite limited, the stone is readily accessible in large quantities. It has been opened up principally near the mouth of Rock creek north of Ollie. Quarries are now operated for local purposes only. S. C. Cook opened up a quarry here and built a switch connecting it with the Iowa Central railway at Ollie. The quarry has not been worked for some time but is to be reopened shortly.

Across Rock creek from this opening is the Riley Fye quarry which supplies the principal local trade. Nearer the mouth of the stream is the Fye Brothers quarry, and the Weber quarry, the latter supplying the stone used at the Manhattan mill dam.

SOILS.

There are two well marked soil types in this county, both of which are derived from the Pleistocene deposits. The indurated rocks are exposed so rarely that residual soils are not found. While there is considerable variety in the glacial deposits the variety does not extend very largely to the soils. Sometimes at or near the close of the glacial period the uplands become covered by a mantle of loess. This has since been altered considerably and forms the more common soil type. The upper portion is oxidized and mixed with humus, giving it usually a black appearance as seen in the field. The subsoil is a fine grained, usually tough, gray clay. It is normally free from gravel and seems to be an altered form of the loess which has lost its porosity to a considerable extent. Indeed, this change has advanced so far that where there is not a good natural drainage tiling must often be resorted to. Fortunately this same material is excellent for the manufacture of tile.

The second soil type is the alluvium which is found covering the bottom lands. It is simply the upper, blacker portion of the soil just described, and which has been washed down from the hills and re-deposited. This re-deposition has given it a loose, open texture. It is usually of considerable thickness, and since it lies down close to the water does not readily dry out. In some places it must be under-tiled.

Along the upper hillsides the soil proper has frequently been washed away, leaving the boulder clay exposed. This is, however, rarely the case except upon hillsides steeper than are cultivated, so that the boulder clay need not be considered as a soil.

WATER SUPPLY.

This county is well watered. The two river systems, with their numerous tributaries, supply an abundance of water for general and stock purposes. The thick mantle of drift with the diverse character of the different layers, makes it easy to obtain a good well at almost any point. At Sigourney there are several well marked water horizons in the drift. They are at depths of twenty-five, fifty-five, seventy and eighty-four to ninety-eight feet. In the first three cases the water is encountered in loose gravel or gravelly clay beds lying above layers of "hard pan" or "gumbo," while in the remaining instance the water-bearing gravel lies above the Saint Louis limestone.

It is rarely necessary, in any part of the county, to go into the older rocks for water. The Saint Louis is, however, usually water-bearing, a good supply being found in the soft sandstones lying between the limestone bands. Two such wells have been sunk at Keswick and similar wells have been bored at other points in the neighborhood.

The coal measures rarely furnish good water, a fact causing serious difficulties in mining regions. At What Cheer extensive prospecting has so far failed to reveal any good supply and surface waters are used. The Augusta is not water-bearing.

Two deep wells have been sunk in the county, one at What Cheer and one at Sigourney. Neither proved to be flowing wells, though in each case some water was found. At the latter

point a vein of mineral water with a strong odor was encountered at a depth of 1,320 feet. At 1,360 feet in the same stone a strong current of fresh water was struck which increased in force down to 1,388. This water flowed over the top while the drill was in motion, but now stands within about thirty feet of the top. It is of excellent quality and is unlimited in quantity, but it has never been used to any great extent.

WATER POWER.

The fuller utilization of the power of our streams is a subject which is now attracting considerable attention. In the earlier days when distance was more considered, industry less closely organized, and manufacturing methods more primitive, the streams of this region were more completely utilized. At nearly every available point dams were built and the power made to grind grains or weave wool. The advent of railroads and the introduction of more expensive machinery, dealt a death blow to these industries, till to-day for one such mill in operation there are many which are abandoned. Yet the streams have as much power as before, and power is probably in even greater demand than in earlier times. The problem is how economically to use the power. In many portions of the country the solution is being found in the introduction of electricity. When power is transformed to electricity it may be easily and cheaply transferred to some distance and applied to a variety of purposes. More usually it has been used directly as electricity in lighting.

The gradient of the Skunk rivers is quite low so that the power must be gathered rather by numerous smaller dams than by a few large ones. On North Skunk there are five mill sites, two of which, the Delta and the Black Hawk, are now in use. The remaining three have been abandoned. On South Skunk there is one mill site now used, the Manhattan, and two which are abandoned. At present not to exceed 240 horse power from this source are used. With very little expense about 1,000 horse power could be obtained. The experience of a number of years has shown that it very seldom occurs that there is not sufficient water in the river to meet all demands, and it seems

not improbable that sooner or later this waste power will be economically applied.

ROAD MATERIALS.

The value of good roads is becoming more and more generally recognized, and studies of their construction and the materials available are becoming popular. In Keokuk county there are two materials which are readily available, stone and clay. The gravel beds are of local extent only, and while of considerable value when found are badly scattered. The stone used must in the main be limestone since most of the sandstone is too soft. Nearly all the limestone found in the county could be readily used for macadam work. Certain of the Saint Louis strata are especially valuable owing to their hard compact nature. The distribution of these limestones has already been given in considerable detail.

In some quarters railways have used burned clay as a ballast. It is easily and cheaply prepared and makes a fine road material. Immense quantities of suitable clay are found all over the county.

Near What Cheer the old dump heaps of deserted mines are being used to some extent on the roads with excellent results.

LIME.

Formerly lime was burned from both the Augusta and the Saint Louis formations at a number of points. Of recent years the competition of more favored lime regions in the eastern part of the state has caused the abandonment of most of these kilns. At present only one is in operation, that of Mr. J. F. Kline near Hayesville. The stone burned is from the middle Saint Louis and a fine grained lime of good strength is obtained.

MINERALS.

Keokuk county is not a mineral district and any expectations of sudden wealth based upon discoveries of precious metals must lead to disappointment. Gold has been found in limited quantities at a few points in the drift or in rocks from the drift. It is not probable that it will ever be found in paying quantities.

Through the Kinderhook, Augusta, Saint Louis, and even coal measures of this region there are bands of chert or quartz. It has recently been found that some of these at least bear silver in limited quantities, one specimen assayed being said to have shown thirteen ounces to the ton. It does not, however, seem probable that these cherts will ever have any real value.

MINERAL PAINT.

Near Hayesville is a deposit of red ocherous clay which was at one time used locally as a crude paint. The deposit has never been developed.

STATISTICS.

The total production of the various minerals found in Keokuk county is shown for the year 1893 in the following table:

Coal—		
Amount—tons	270,350	
Value		$427,153.00
Clay—		
Brick—		
Amount	2,810,000	
Value		20,280.00
Tile—		
Amount	3,080,000	
Value		34,750.00
Building stone—		
Amount—perches	60	
Value		750.00
Total value		$482,933.00

ACKNOWLEDGMENTS.

In the preparation of this report help has been received from a large number of individuals. It is impossible to mention all of these by name. Among those, however, to whom the author is particularly indebted must be mentioned Captain Parker, of Sigourney; Mr. E. R. Gildroy, Mr. E. M. Trescott, Mr. Samuel Gildfay, and Mr. S. W. White, of What Cheer. To these and the many others who have so courteously helped sincere thanks are given.

GEOLOGY OF MAHASKA COUNTY.

BY

H. FOSTER BAIN.

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CONTENTS.

INTRODUCTION.

AREA AND LOCATION.

Mahaska county is located in about the middle of the southeastern portion of Iowa. It is bounded on the north by Jasper and Poweshiek, on the east by Keokuk, on the south by Wapello and the west by Monroe counties. It includes townships 74 to 77 north, ranges XIV to XVII west; an area of 576 square miles, or 386,640 acres.

PREVIOUS GEOLOGICAL WORK.

This county has long been noted as a great coal-producing county and has been visited at different times by several geologists. Owen*, in his reconnoissance up the Des Moines river in 1849, noted several outcrops of sub-carboniferous limestone within its limits, called attention to the coal of the Muchakinock valley then already mined to a slight extent, and described the sandstone at Raven Cliff. In 1856 Worthen† passed over the same ground, but added little information. In 1867 White‡ visited the county and called attention to the presence of Saint Louis strata in the beds of the Skunk river. He described the mines then in operation and emphasized the abundance of the coal present.

PHYSIOGRAPHY.

TOPOGRAPHY.

This county may be conceived as a rolling plateau sloping gently from an elevation of 915 feet in the northeast to about 750 feet in the southwest. Across this plain running approximately parallel from northwest to southeast are three main river valleys and three minor ones which have greatly affected the topography of the district. In crossing from a northeast to a southwest direction a series of four low ridges or watersheds would be encountered, the tops just touching the ideal plain

*Geol. Sur. Wisconsin, Iowa and Minnesota. 114-116. 1852.

†Geology of Iowa, II, 165-166. 1858.

‡Second Ann. Rep. State Geologist, 91-93. 1868.
Geology of Iowa, II, 265-267. 1870.

mentioned above. The erosion of this section has been so vigorous and so widespread that over the greater portion of the county the actual aspect of a plain has been greatly obscured.

In that portion of the county northeast of the North Skunk river the plateau character is still the main feature of the landscape. In this region the land varies in elevation from 910 to 885 feet in elevation; the streams, away from the river, cutting but little below that level. The North Skunk river itself has cut below this plain from ninety to one hundred feet. Its direct tributaries here are mainly from the north so that it is on this side that the greatest amount of erosion has taken place. South of the river the bluffs are usually well marked and follow close along the river.

The strip of country lying between the North and South Skunk rivers, preserves toward the west the plateau feature; particularly over the greater part of Prairie township. Near Peoria, and over the greater part of Richland township, the plain has been badly cut up by Buckley creek and its branches. Toward the east division of this plateau becomes more and more well marked; Middle creek running down its center, or a little south of the center, leaving a ridge on either side between it and the respective branches of the Skunk. The north ridge is the greater and has an elevation varying from 876 feet at New Sharon, down to 843 at Tioga. Below this level Middle creek cuts ninety-three feet, while the second ridge, upon the crest of which the town of Lacey is built, rises fifty-eight feet above Middle creek. From Lacey south the slope is quite abrupt to the bottom lands of the Skunk river at 718 feet.

The high land between the South Skunk and the Des Moines river, which at Oskaloosa rises to 843 feet is likewise divided by the valley of the Muchakinock which flows centrally through its western part. This valley is quite deep, being at Evans cut down to 734 feet, though it is not large and has few side valleys of any extent. From Oskaloosa southeast the plainlike aspect becomes more prominent. Cedar creek does not greatly roughen the topography, and in general the southeastern part of the county may be considered a gently rolling plain varying in elevation from 850 to 880 feet.

The Des Moines valley is deep and usually broad. Harvey, just west of the county line, and built on the flood plain of the river, lies at an elevation of 718 feet. Eddyville with a similar location where the river crosses the south county line, is 677 feet above sea level.

The portion of this county lying southwest of the Des Moines river is quite broken. The uplands are 120 to 160 feet above the Des Moines. The creeks have usually broad bottom lands and numerous tributaries.

The topographic forms observed throughout the region are those common to regions covered by drift and altered by erosion. The hills are usually low with gentle rounded slopes. Where the rivers cut across the hardened indurated beds, high steep bluffs are occasionally seen. In some cases these beds, as for example the Saint Louis along South Skunk northeast of Oskaloosa and along the Des Moines opposite Eddyville, form well marked terraces skirting the river. In these cases it seems that the stream after cutting out the larger valley in the drift was unable to excavate its channel as rapidly in the harder rocks below.

Table of Elevations.

LOCALITY.	ELEVATION*.	AUTHORITY.
Atwood	722	C., R. I. & P. Ry.
Barnes	915	B., C. R. & N. Ry.
Beacon	736	C., R. I. & P. Ry.
Cedar	872	Survey.
Eddyville	677	Iowa Central Ry.
Evans	743	C., R. I. & P. Ry.
Fremont	888	Survey.
Given	705	Iowa Central Ry.
Harvey	718	C., R. I. & P. Ry.
Lacey.	841	Iowa Central Ry.
Leighton	769	C., R. I. & P. Ry.
New Sharon	876	Iowa Central Ry.
North Skunk	780	Iowa Central Ry.
Olivet	818	C., R. I. & P. Ry.
Oskaloosa	843	C., R. I. & P. Ry.
Rose Hill	822	C., R. I. & P. Ry.
Stark	856	Survey.
Tioga	834	C. & N.-W. Ry.
South Skunk bridge	715	Iowa Central Ry.
E. Co. line 1 mile west Nassau	910	B., C. R. & N. Ry.
Stream near Barnes	895	B., C. R. & N. Ry.
River at Atwood	695	C., R. I. & P. Ry.
South Skunk west of Rose Hill	718	Survey.
North Skunk, Atwood	695	C., R. I. & P. Ry.

*Above sea level.

In this table the elevations credited to the different railways are taken from the engineer's profiles and reduced to sea level. Those credited to the Survey are based on barometric observations corrected and tied to railway levels.

DRAINAGE.

Though there is a slight general slope of the present surface from the northeast to the southwest the main drainage lines of the county run at right angles to this slope.

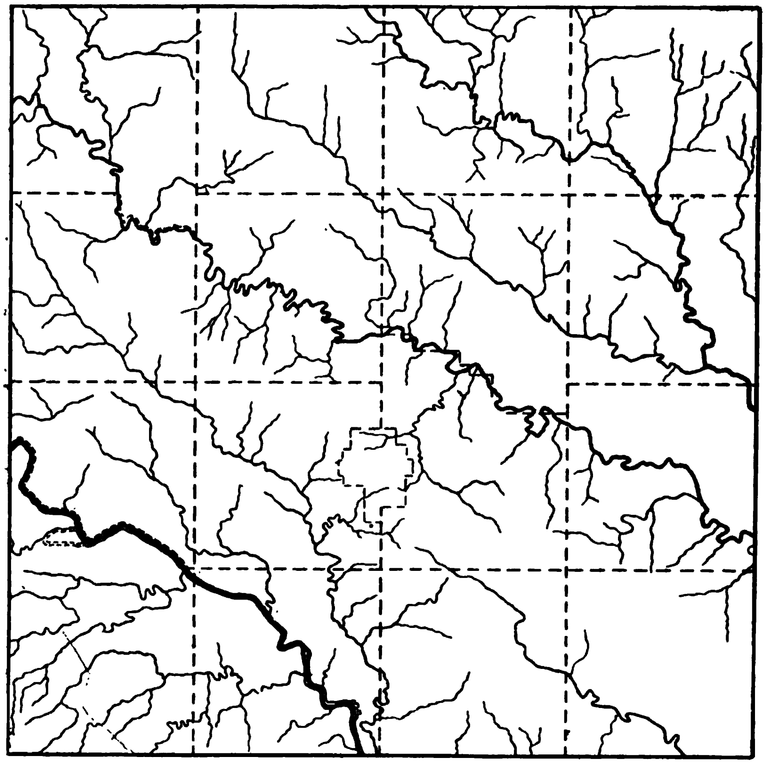

Figure 30. Drainage of Mahaska county.

In the extreme northeast corner of the county is the South English river, here an insignificant prairie stream. This region belongs to the drainage system of the Iowa river. The North Skunk river enters the county almost directly north of

New Sharon. It flows in a southeasterly direction, receiving from the north Buck creek, Moore creek and Pleasant Run, and from the south, near the east county line, Middle creek, which takes its rise well toward the northwestern corner of the county. North Skunk throughout a considerable portion of its course has cut through the drift and into the indurated rocks exposing both coal measures and underlying beds. Its tributaries do not show exposures of the older strata any considerable distance from the river.

South Skunk river enters the county about three miles south of the northwest corner and leaves it about seven miles north of the southeast corner. It is of considerable size, though the presence of parallel streams at a short distance, makes its tributaries in this county few and insignificant. The more important are Buckley creek, flowing from the north near Peoria, and Spring creek coming from the south near Oskaloosa.

Muchakinock creek is formed by the union of two small streams near Leighton. From here it flows southeast eight miles to Beacon, from which point it flows slightly east of south to the Des Moines river, with which it unites a short distance below Eddyville. It does not receive many tributaries, Kennebec and Lost creek, both flowing in from the east, being the most important.

The Des Moines river crosses the southwestern portion of the county, entering it about ten miles north of the southwest corner and leaving it about the same distance east of the same point. The upper portion of its course especially shows the record of important changes. Near the mouth of Cedar creek a recent cut off makes a change of nearly four miles in the course of the river. Farther down the river is not so sinuous. The valley is quite broad and deep. The bluffs along the river rise abruptly 120 to 150 feet with a still farther, but more gradual rise back from it of twenty to fifty feet more. The most important tributary which the river receives from the east is Saint Joe creek, which rises well toward the northeast corner of Scott township, flows southeast six miles back of the hills, cuts through the bluffs, runs three miles along the eastern edge of the Des Moines flood plain, and thence west to the river.

On the south side of the Des Moines the drainage lines all run toward the northeast, the river receiving three important streams from this direction, Cedar creek, Coal creek and Bluff creek. These streams have numerous branches and thoroughly drain the region.

In addition to the streams mentioned above there are two others, Cedar creek, in the northeast portion of the county, flowing southeast through Keokuk county to the North Skunk, and Cedar creek in the southeast portion of the county flowing southeast through Wapello and Jefferson counties.

STRATIGRAPHY.

General Relations of Strata.

The surface deposits of Mahaska county consist of the unconsolidated material of Pleistocene age. Below this are the indurated rocks of the Carboniferous. Along the principal stream the Lower Carboniferous or Mississippian rocks are exposed, while over the upland the Upper Carboniferous (coal measures) lie between these rocks and the drift.

Classification of Formations.

GROUP.	SYSTEM.	SERIES.	STAGE.	SUB-STAGE.
Cenozoic.	Pleistocene.			Alluvium Loess. Drift.
Paleozoic.	Carboniferous.	Upper Carboniferous.	Des Moines.	
		Mississippian.	Saint Louis.	Pella. Verdi.

The indurated rocks of Mahaska county are made up in the main of coal measure strata. These consist largely of shales of all varieties, ranging between the three extreme types of

argillaceous, arenaceous and bituminous. Every gradation between the three, the first a firm, black fissile bituminous shale, the second a loose, coarse, sandy shale and the third a fine grained, compact, blue to gray, argillaceous shale is exhibited. Sandstone also forms a considerable portion of the deposits. It usually exists in thick, heavy beds or as lenses in sandy shales. Coal seams are of not infrequent occurrence, but limestones are rarely found. These rocks spread over the entire county with the exception of certain narrow strips along the streams where they have been cut entirely through and the lower beds are exposed. These lower beds, which belong to the Mississippian or Lower Carboniferous, consist almost entirely of limestones. The upper beds contain thin layers of marl which are usually crowded with various fossils. Below these marly layers the limestone becomes in places interstratified with sandstone bands. The limestone is usually fine grained, compact, ash to brown in color and splits with a clean, conchoidal fracture. The intercalated layers are frequently of considerable thickness. These beds rise at various places along the principal water courses from two or three to as much as fifty feet in height. They usually exhibit sharp, clean bluffs and good exposures. The distribution of the Saint Louis is somewhat irregular. While it is only seen in the neighborhood of the larger streams, it is known to occur at no great depth below the surface at numerous other points.

The surface materials of Mahaska county are in common with those of the surrounding region of Pleistocene age. They are made up largely of till, sand and gravel, loess and alluvium; the latter being found along all the different streams.

DEEPER STRATA.

Our knowledge of the deep-seated rocks underlying Mahaska county is quite limited. It must be derived entirely from the results of deep borings made in neighboring counties. A deep well was put down at Oskaloosa, but the record of the strata passed through does not seem to have been kept with sufficient accuracy to render it valuable for purposes of geological correlation.

A deep well was put down at Sigourney* in the county just east, and it is probable that a well put down in Mahaska county would encounter essentially the same strata.

TYPICAL SECTIONS.

ON NORTH SKUNK RIVER.

MEYERS SECTION.

(Tp. 77 N., R. XVI W., sec. 1, Nw. qr., Se. ¼.)

		FEET.	INCHES.
7.	Drift	2	
6.	Sandstone, white, fine grained, with plant remains	2	
5.	Shale, bituminous	12	
4.	Coal	1	2
3.	Fire clay	1	6
2.	Shale, in part bituminous	10	
1.	Limestone, in ledges of 5 to 20 inches	6	

Of the above section numbers 2 to 6 represent the Des Moines stage, number 4 is Saint Louis. Borings show sixty feet of limestone below the base as exposed.

WILLIAMS MINE SECTION.

(Tp. 77 N., R. XV W., sec. 9, Nw. qr, Sw. ¼.)

		FEET
5.	Drift, variable	12
4.	Shale, bituminous, containing limestone band one foot thick	14
3.	Coal	4½
2.	Fire clay, variable in thickness from 0 to 5 feet	2½
1.	Sandstone, massive, exposed	2

All of the above section below number 4 belongs to the coal measures. Number 1 is partially exposed at the neighboring bridge over North Skunk.

UNION MILLS SECTION (*a*.)

(Tp. 77 N., R. XV W., sec. 23. Sw. qr., Se. ¼.)

		FEET.
4.	Drift	4
3.	Glaciated boulders in irregular line	1½
2.	Marl, blue, arenaceous	8
1.	Limestone	5

*Proc. Iowa Acad. Sci., vol. I. pt. iv., pp. 36-38. Des Moines, 1894.

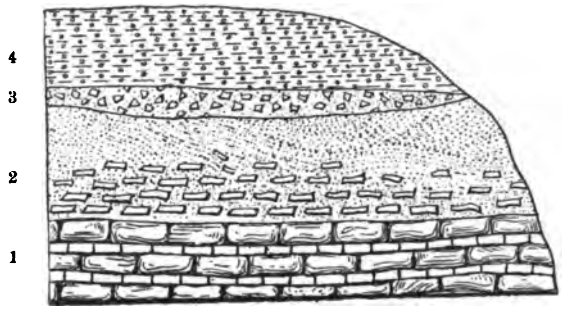

Figure 31. Quarry at Union Mills.

Numbers 1 and 2 of the above are Saint Louis. The coal measures do not appear at the river edge though known to underlie the drift a short distance back on the hill.

UNION MILLS SECTION (*b*).

(Tp. 77 N., R. XV W., sec. 23. Nw. qr., Se. ¼.)

		FEET.
3.	Drift	12
2.	Shale, bituminous	26
1.	Limestone	6

The limestone of the above section belongs to the Saint Louis. The shale is imperfectly exposed in the lower part and a coal seam may be concealed there.

DRIFT SECTION.

(Tp. 77 N., R. XIV W., sec. 30, Sw. qr.)

		FEET.
4.	Soil	3
3.	Loess	20
2.	Clay, yellow with gravel	10
1.	Alluvium of flood plain	10

The soil graduates into the loess, the latter being slightly modified to a depth of at least three feet.

ROBERTS MILL SECTION.

(Tp. 76 N., R XIV W., sec. 4, Nw. qr., Ne. ¼)

		FEET.
1.	Limestone with sandstone interbedded; imperfectly exposed (Saint Louis)	12

MC BRIDE MILL SECTION.

(Tp. 76 N., R. XV W., sec. 15, Sw. qr.)

		FEET.
6.	Limestone, gray, sub-crystalline with interbedded fossiliferous marl layers	10
5.	Unexposed	11
4.	Limestone, ash grey, compact	1
3.	Sandstone, soft, yellow	1
2.	Limestone, as above	2
1.	Sandstone, as above	2

Numbers 1 to 4 are seen under the east pier of the bridge crossing the river at this point. They apparently represent the upper Verdi beds. Number 6 is seen in a small, now disused quarry about 200 yards west of the mill. The hills here rise ninety-five feet above the river and apparently are made up mainly of drift.

COLUMBIA MILL SECTION.

(Tp. 76 N., R. XIV W., sec. 36, Ne. qr., Sw. ¼.)

		FEET.
7.	Boulder clay, yellow	30
6.	Sand	2
5.	Boulder clay, blue	40
4.	Shale, sandy, in part bituminous	15
3.	Coal	6
2.	Fire clay	3
1.	Sandstone, coarse, ferruginous	15

The whole section may be referred to the coal measures. The sandstone, No. 1, is exposed in the wagon road near the mine where it lies at a higher level than under the coal farther east. The shale No. 4 is absent over a considerable portion of the coal field. The coal lies on a level only slightly above the water in the river.

ATWOOD SECTION.

(Tp. 75 N., R. XIII W., sec. 8, Ne. qr.)

		FEET.
5.	Sandstone, coarse, quartzose	2 to 4
4.	Limestone, compact, fine grained	1½
3.	Sandstone as above	3 to 8
2.	Limestone as above	2½
1.	Sandstone as above	15

This section is exposed in a railway quarry in Keokuk county, a short distance east of the Mahaska county line. It

Figure 82. Verdi beds near Atwood.

belongs to the Verdi beds of the Saint Louis which may be seen, not so well exposed, rising twenty feet above the river less than a half mile below the Columbia mine.

ON SOUTH SKUNK RIVER.

THUNDER CREEK SECTION.

(Tp. 77 N., R. XVIII W., sec. 25, Se. qr.)

		FEET.
7.	Sandstone, coarse, quartzose, yellow	2
6.	Limestone, compact, fine grained	1½
5.	Sandstone, coarse, massive, yellow	3
4.	Sandstone as above, with interbedded limestone bands	3
3.	Sandstone, massive, yellow	3
3.	Sandstone, with interbedded limestone, in places conglomeratic	6
1.	Sandstone, coarse grained, cross-bedded; to waters edge	12

This exposure is in Marion county near where Thunder creek flows into the river. The beds are Saint Louis, belonging apparently to the upper part of the Verdi.

BALLENGER'S BRANCH SECTION.

(Tp. 76 N., R. XVII W., sec. 11, Nw. qr.)

		FEET.
2.	Marls, calcareous, in part laminated	2
1.	Limestone, grey, sub-crystalline	2

The outcrop is directly opposite the mouth of Ballenger's branch and down close to the river. From the wall was collected *Productus ovatus*, (?) *Rhynconella ottumwa*, *Spirifer littoni* and other Saint Louis forms.

WATER WORKS SECTION.

(Tp. 76 N., R. XIV W., sec. 25, Sw. qr., Se. ¼.)

		FEET.
3.	Drift	30
2.	Shale, bituminous, thickening under the hill	6
1.	Limestone, fine grained, compact	12

This exposure is seen immediately below the Oskaloosa city water works. The limestone is Saint Louis and quite fossiliferous, bearing the Pella fauna. It extends along the river some distance, varying considerably in exposed thickness. The coal measure shales above it are not here exposed to their full thickness.

SPRING CREEK SECTION.

(Tp. 75 N., R. XV W., sec. 4, Nw. qr.)

		FEET.
5.	Limestone, thin bedded, with fossiliferous marls	2
4.	Limestone, compact, grey	2
3.	Limestone, fine grained, white	10
2.	Sandstone, calcareous	4
1.	Unexposed	10

Number 2 of the above section is seen on Spring creek near its mouth. Number 3 is exposed farther up the creek and has been quarried for lime. Numbers 4 and 5 are exposed immediately below the mouth of the creek on the river.

CURRIERS MILL SECTION.

(Tp. 75 N., R. XIV W., sec. 7, Se. qr., Nw. ¼.)

		FEET.
2.	Drift	60
1.	Sandstone, soft, yellow; in irregular layers interbedded with sandy shale, becoming argillaceous toward the base	50

ROSE HILL BRIDGE SECTION.

(Tp. 75 N., R. XIV W., sec. 15, Sw. qr.)

		FEET.
1.	Limestone, brecciated (Saint Louis) exposed 30 feet above the river	10

TIOGA SECTION.

(Tp. 75 N., R. XIV W., sec. 14, Sw. qr.)

		FEET.
1.	Sandstone, soft, yellow, with heavy cross-bedding extending along the river a mile or more; capped in places by limestone	35

HOWELLS MINE SECTION.

(Tp. 75 N., R. XIV W., sec. 36, Nw. qr.)

		FEET.	INCHES.
6.	Drift	30	
5.	Shale, bituminous	12	
4.	Coal	1	10
3.	Fire clay	1	6
2.	Sandstone	6	
1.	Unexposed to river	10	

Farther up the river from this mine, as well as a short distance below it, the middle portion of the Saint Louis is seen to rise a considerable distance above this coal seam, the latter resting in an erosion channel in the former.

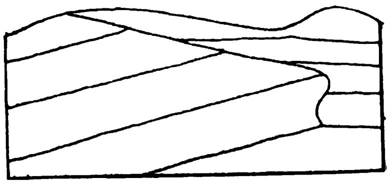

Figure 33. Lines of cross-bedding seen in the sandstone near Tioga.

The upper part of the Saint Louis outcrops near here, is not always clearly exposed, but may be seen at several places to consist of limestone. The sandstone below it is well exposed, the irregular cross-bedding frequently being quite prominent, as shown in the sketch.

ON DES MOINES RIVER.

HARVEY SECTION (a).

(Tp. 75 N., R. XVIII W., sec. 4, Nw. qr., Sw. ¼.)

		FEET.
3.	Drift and loess exposed	10
2.	Grey and ash colored marl with abundant fossils	5
1.	Limestone, blue, weathering brown in places, thinly bedded above (exposed)	12

From number 2 of the above section Dr. Keyes collected *Pentremites konickiana* Hall; *Spirifer littoni* Swallow; *Zapherentis pellœnsis* Worthen; *Athyris subquadrata* Hall; *Productus marginocinctus* Prout and other forms.

HARVEY SECTION (*b*).

(Tp. 75 N., R. XVIII W., sec. 12.)

		FEET.
3.	Loess and drift	12 to 30
2.	Coal, impure; in part shaly, badly weathered	12 to 15
1.	Clay ironstone, nodules covered with cone-in-cone, partly exposed	3

This is the locality mentioned by Owen for the occurrence of "tutenmergel." The exposure stretches along the river half a mile or more. A short distance below (Tp. 75 N., R. XVII W., sec. 18) is an exposure of Saint Louis as follows:

		FEET.
2.	Limestone, fine grained, blue	12
1.	Sandstone, white, calcareous	8

The outcrop stretches some distance along the river. The section given was measured near the center of the exposure.

BELLEFOUNTAINE (*a*).

(Tp. 75 N., R. XVII W., sec. 19.)

		FEET.
3.	Drift	55
2.	Sandstone, and sandy shales, imperfectly exposed	104
1.	Limestone, with irregular cross-bedded sandstone layers	15

The lowest member of this section is the Saint Louis, and seems to resemble the middle or Verdi beds. It is well exposed on the west side of the river, immediately above the ford. Number 2 represents the coal measures as seen in the hills east of the river.

BELLEFOUNTAINE SECTION (*b*).

(Tp. 75 N., R. XVII W., sec. 3, Se. qr.)

Near the mouth of Cedar creek is seen the section shown in the following figure. The measurements represented are about 200 feet for the horizontal and seventy-five for the vertical. The sandstone at the base is capped by eight feet of compact,

somewhat earthy limestone. Both have been deeply eroded by an ancient water course having a channel with an east and west trend. This channel is filled with dark clay and shale, the

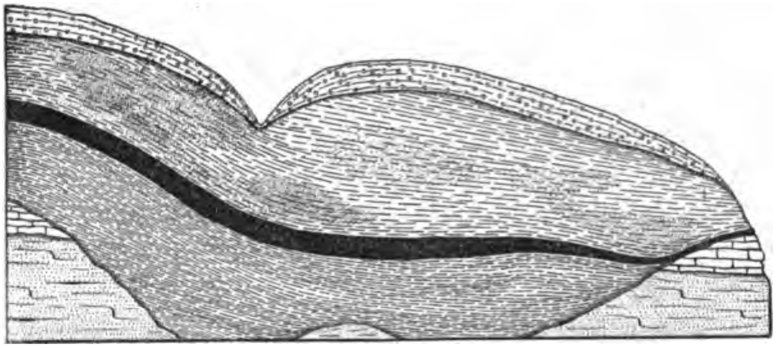

Figure 34. Coal Measures resting unconformably upon Saint Louis; Bellefountaine.

whole rising fifty-five feet above the river. There is a bed of coaly shale, somewhat irregular and rising rapidly toward the east where it is four feet in thickness. Toward the west it thins out to about eighteen inches, rising over the limestone. This layer is covered by thirty to forty feet of argillaceous and sandy shale.

RAVEN CLIFF.

(Tp. 75 N., R. XVII W., sec. 32 and 33.)

This cliff is 137 feet high, and is made up of a coarse grained coal measure sandstone having a dark red color. It extends down to within ten feet of the river, the base being concealed. The stone is massive and gives in places single precipitous faces of fifty or more feet. The exposure extends nearly two miles along an old deserted arm of the river. Near the west end is a small coal seam, probably continuous with the coaly layer mentioned in the preceding section, and lying well toward the base of the sandstone. Immediately below the cliff, well diggings reveal the presence of the upper fossil bearing portion of the Saint Louis at a level slightly above the base of the sandstone.

COAL CREEK SECTION.

(Tp. 74 N., R. XVII W., sec. 1, Ne. qr.)

		FEET.
2.	Shale, bituminous, exposed	2
1.	Limestone, grey	12

In this section the lower member is the Saint Louis, seen at the river. The upper member belongs to the Des Moines beds and is exposed a short distance from the mouth of Coal creek.

GIVEN SECTION.

(Tp. 74 N., R. XVI W., sec. 10, Sw. qr.)

		FEET.
2.	Shale, argillaceous, drab to black	20
1.	Limestone, compact, grey	2

The lower member (Saint Louis) is seen at the river's edge directly west of Given. The upper member (coal measures) is exposed a short distance from the mouth of a small stream flowing into the river at this point.

BLUFF CREEK SECTION.

(Tp. 74 N., R. XVI W., sec. 23, Nw. qr.)

		FEET.
6.	Loess	15
5.	Sand, yellow	5
4.	Gravel, coarse, with erratics	1
3.	Limestone, thin bedded above, heavier below	12
2.	Sandstone, soft	4
1.	Unexposed to river	15

This section is exposed on the east side of the river opposite the mouth of Bluff creek. The surface of the limestone very plainly shows the effect of water erosion.

EDDYVILLE SECTION.

(Tp. 73 N., R. XVI W., sec. 1, Ne. qr., Ne. ¼.)

		FEET.
5.	Drift	20
4.	Shale, bituminous	3
3.	Coal	4½
2.	Fire clay, grading below into shale	20
1.	Limestone, grey, compact, imperfectly exposed	70

The limestone (Saint Louis) is well exposed here along the river on both sides. The coal seam is not now worked.

Geological Formations.

MISSISSIPPIAN SERIES.

The Carboniferous rocks of the Mississippi valley may be divided into two series: (1) Mississippian (Lower Carboniferous). (2) Upper Carboniferous. The former is represented in

Iowa by three formations, the Kinderhook, Augusta and Saint Louis. The Kaskaskia which, in Missouri overlies the Saint Louis, is not present over this region. Of the three divisions of the Mississippian series present in Iowa, only the upper is exposed in Mahaska county.

SAINT LOUIS.

The oldest rocks exposed within the limits of the county belong to this terrain. Their surface, which is characterized by great irregularity, lies at a general level about 120 feet below the present surface. Thus it happens that these rocks are only exposed along the major streams. As a general statement it may be said that the flood plains of the North and South Skunk and Des Moines rivers are underlaid by the Saint Louis. This is not, however, everywhere true of any of these streams.

On the North Skunk river the Saint Louis is exposed north of New Sharon at the Peter Meyer's quarry, the section of which has already been given. Below here no Saint Louis appears until Union mills is reached, the interval being occupied by the beds of the Des Moines terrain, which are seen to lie at or below the level of the water.

The Saint Louis is well developed at the McBride mill and extends down the river from this point a mile or more. It is succeeded by the coal measure area in which the Columbia Coal mines are located, and which is, in turn, abruptly cut off by the Saint Louis extending up the river from Atwood.

On the South Skunk river the Saint Louis is well developed at numerous points as seen in the sections already described. Directly east of Oskaloosa, at Currier's mill, is an area extending along the river nearly two miles in which the coal measures are well exposed down to the water's edge. At each end of this area they are quite abruptly replaced by Saint Louis. A similar instance is seen at Raven Cliff where it seems probable that the coal measure sandstone extends down to the water's edge, though this can not be determined.

With the exceptions just enumerated the Saint Louis will be found to underlie the bottom land of these rivers. In the southeastern portion of the county on Cedar creek (Tp. 74 N.,

R. XIV W., sec. 29, Se. qr., Ne. $\frac{1}{4}$) a ledge of rock was formerly exposed and some stone taken out for foundation work. The loose blocks remaining on the surface show this to have been Saint Louis. North of Fremont the same rock is exposed along all the streams and it is not improbable that it may directly underlie a portion of this land. The surface is covered with drift and there are no indications by which such areas if present may be separately mapped. Their determination must accordingly be left to future prospecting with the drill.

While the very great irregularities in the surface of the Saint Louis already mentioned, importantly modify the statement, yet in general it is true that the Saint Louis lies under the hills at about the same level as along the streams.

Lithologically the formation is made up largely of limestones. Sandstones form however a not unimportant portion of the formation particularly in the southeastern portion of the county. The limestone is usually a compact, fine-grained, ash grey to blue variety, with a conchoidal fracture. It is in layers usually from six to twenty-four inches in thickness though in places it is thinner bedded. The stone is usually quite frèe from impurities and burns readily to a good quality of lime; often however it takes on an arenaceous or bituminous facies. The latter is not as common in Mashaska county as in counties farther south and east. At certain points the upper layers of the limestone are interbedded with light calcareous marls which are exceedingly fossiliferous. This is characteristic of the upper portion of the formation. The lower portion of the Saint Louis in this county becomes decidedly arenaceous.

Near Bellefountaine is an interesting exposure (Bellefountaine section a) in which the sandstone layer No. 1, is heavily cross-bedded. Between the sandstone layers there is a thin development of limestone which in weathering stands out and thus brings out prominently the lamination plains. This is represented in figure 35, from a photo taken just above the ford.

In the region adjoining Mahaska county the Saint Louis formation is seen to be made up of three series of beds. The uppermost member is most markedly calcareous, being made up largely of heavy bedded limestones. In its upper portion

the strata becomes thinner bedded and the interstices are filled with a light, calcareous marl which is exceedingly fossiliferous. From the excellent exposures near Pella, in Marion county, these have been called the Pella beds.

The median member of the Saint Louis, the Verdi beds, is the thickest and the one most prominently developed in southeastern Mahaska, southern Keokuk and southwestern Washington counties. It is characterized by a great diversity of

Figure 85. Cross-bedded sandstone near Bellefountaine.

structure containing, as it does, limestones, sandstones and breccias. The formation is prevailingly arenaceous as contrasted with the formations lying above and below it. The sandstones are usually interbedded with thin limestone bands which are frequently more or less cherty in appearance, but in places clear sandstones of considerable thickness are encountered. The brecciated beds, while quite prominent south and east of here, are not often exposed in Mahaska county.

The basal member of the Saint Louis as developed in this region consists of twenty to twenty-five feet of blue calcareous shale, becoming in places an earthy or an arenaceous limestone

and weathering readily into a soft brown mass. This subdivision, which has been called the Springvale beds, does not appear within the limits of Mahaska county.

The sections already described as the Meyer's section, Union Mills section, the upper portion of McBride Mill section, Ballinger's Branch section, Water Works section, upper part of the Spring Creek section, Harvey section, lower part of the Raven Cliff and the Given sections, the Bluff Creek section and the limestone of the Eddyville section, may all be referred to the Pella beds. The Roberts Mill section, the lower part of the McBride Mill section, the Atwood section, the Thunder Creek section, the Rose Hill Bridge section, the Tioga section, and the Bellefountaine sections, may be referred to the Verdi beds. The character of the two formations, as developed in this county, is sufficiently indicated by the details of these sections.

UPPER CARBONIFEROUS SERIES.

The coal measures of Iowa are composed of two different stages, the lower or Des Moines, and the upper or Missouri. Of these the Des Moines terrain is alone present in the region under immediate consideration, the Missouri being represented in the marine deposits of the southwestern portion of the state.

DES MOINES STAGE.

Practically the entire county, with the exception, as already noted, of the low land along the major streams, is underlaid by the beds of this terrain. The general surface of the upland region, as may be seen by referring to the table of elevations, varies in altitude from 822 to 915 feet. This difference is due entirely to the irregularities of the present surface and affects the thickness of the drift formation only. The low lands along the streams vary in elevation from 695 to 718 feet. There is thus an average difference of from 120 to 150 feet between the upland and the lowland. The upper surface of the Saint Louis, as has been explained, is very irregular, yet its general elevation is in the neighborhood of 725 feet, so that almost the entire difference between the upland and the lowland may be reckoned as made up of coal measures and drift.

The relative proportion of these two is not constant. In places the coal measures are entirely absent, the drift resting directly upon the limestone. In others a thickness of sixty feet or more of Des Moines beds intervenes.

As is now well understood the coal measures of this region as a result of the rapid thickening and thinning of the individual strata, are of such an irregular character that no general section which would be true for the entire region can be given. The greater portion of the coal so far worked has been taken from the Muchakinock valley and by reason of the large number of shafts and bore holes put down, the individual strata are perhaps better known here than elsewhere. The following section, being that found at Shaft No. 8 of the Consolidation Coal Co. (Tp. 75 N., R. XVI W., sec. 34, Sw. qr., Se. ¼) is fairly representative.

		FEET.
8.	Drift	18
7.	Shale, grey, argillaceous	32
6.	Coal	1½
5.	Sandstone	4
4.	Shale, bituminous	49
3.	Coal	7
2.	Fire clay, graduating below into grey shale	35
1.	Limestone (Saint Louis)	

Throughout this valley the order of these strata remain approximately the same. The fire clay (No. 2) in the cases where it has been penetrated is usually somewhat thinner, most frequently about twenty feet. Naturally the strata below the coal have not been so thoroughly explored and are not so well known as those above. The bituminous shale (No. 4) is quite constant. The sandstone (No. 5) the upper coal (No. 6) and the grey shale (No. 7) are usually found, though with considerable variation in thickness, wherever they have not been cut away by erosion. An impure, bituminous limestone known as "hydraulic rock" sometimes occurs in the bituminous shale. It frequently happens that the preglacial erosion has cut down into or entirely through the latter.

At the shaft of the Long Brothers Coal and Mining Company in Oskaloosa, the strata present a general agreement with

those of the Muchakinock valley, as seen by the following section:

		Feet.
7.	Drift	60
6.	Sandstone	3
5.	Shale, bituminous	21
4.	Hydraulic rock	1
3.	Shale, bituminous	18
2.	Coal	6½ to 7
1.	Fire clay	4

The full thickness of the fire clay was not here penetrated. The coal, however, is evidently of the same horizon as that formerly worked in the Standard mine just west of Oskaloosa College, at which point it was about twenty-five feet above the limestone. Northeast of Oskaloosa the erosion has cut still deeper, as seen in the mines of the Excelsior Coal Company at Carbonado. Of the coal measure strata overlying the coal at this point, the bituminous shale alone remains, and it does not reach its full thickness. In a slope at mine No. 5, a total thickness of fifteen feet was measured. Its thickness is in parts of the mine still less, and in a few places no shale at all remains. Still farther northeast, in the region between the two branches of the Skunk river, such drilling as has been done, shows that erosion has been even more active; the shale is in most cases quite thin or entirely absent. The coal in this direction also thins considerably, and in only small areas have beds of good workable thickness been so far located.

In the area northeast of the North Skunk river, as shown by the operations of the Columbia Coal Company, the same erosion phenomena occur. The section found here shows only a few feet of shale.

		Feet.
6.	Soil	1
5.	Drift	84
4.	Shale, bituminous	10
3.	Coal	5½
2.	Fire clay	9
1.	Sandstone	

The sandstone in this section is exposed in the road west of the mine. It is seen here to be a coarse-grained, reddish yellow

to white quartzose stone similar to that found elsewhere in the Des Moines terrain. At the exposures the stone lies at an elevation slightly above that in the section described.

The coal measures, as seen at Currier's mill on the South Skunk river, seven miles east of Oskaloosa, consist of fifty feet of interstratified shale and sandstone. The following represents a typical portion of the exposure:

		FEET.	INCHES.
8.	Shale, with intercalated layers of sandstone three to four inches thick	12	
7.	Sandstone, soft, yellow		3
6.	Shale, blue, argillaceous	2	
5.	Sandstone	1	
4.	Shale	1	
3.	Sandstone	6	
2.	Shale		2
1.	Sandstone	6	

The individual layers as shown here are not persistent even throughout the length of the outcrop.

Both of the Currier's mill and the Columbia mine exposures lie between contiguous outcrops of Saint Louis limestone and in each instance the latter rises a considerable distance above the base of the sandstones. In each instance it is also true that the nearest coal lies above the sandstone. At the Columbia mines this fact has been demonstrated by borings. At Currier's mill there is no coal directly above the sandstone, the drift resting immediately upon it. Back on the hill a short distance is the Bacon shaft, a local mine. The section shown here is:

		FEET.
5.	Drift	18
4.	Shale, bituminous	17
3.	Coal	5
2.	Fire clay	2½
1.	Sandstone	

The top of this shaft is 100 feet above the river, so that the sandstone No. 1 may be directly correlated with that exposed at the mill. Drilling carried on between the Columbia mine and Currier's mill tends to confirm the impression gathered from the map that the sandstone exposed at these two points is in reality continuous. West of the mill it has not been

definitely traced though certain borings seem to indicate that it bears south and east.

Sandstones do not in this region form a relatively large proportion of the Des Moines formation. They usually cover but small areas and while they frequently attain considerable thickness, with the exception of the thin bed frequently encountered in sinking shafts in the Muchakinock valley, none have been traced over any great extent of territory. In addition to the sandstone exposed near the Columbia mine and Currier's mill the principal sandstone exposures of Des Moines age are in the neighborhood of New Sharon and at Raven Cliff (Tp. 75 N., R. XVII W., sec. 32 and 33). One mile north of the former point a cut on the Iowa Central railway shows twelve feet of coarse red to yellow sandstone, quite soft and heavily cross-bedded. A sandstone occupying the same position is seen at the Peter Meyers brick yard. At this point it is full of stigmaria.

Near Raven Cliff are some of the most interesting exposures in the county. For a distance of two miles along an old channel of the Des Moines there are extensive exposures of sandstone. The bluff here rises to a total height of 137 feet above the water. Nearly this entire height is made up of coal measure sandstone, it being covered by only a few feet of drift. The stone is massive, quartzose, red to brown, rather soft and standing in single precipitous bluffs as much as fifty-two feet high. The lower ten feet is covered by a narrow flood plain deposit. Toward the south the sandstone runs up against the Saint Louis which rises thirty feet or more above the water. (Tp. 75 N., R. XVII W., sec. 34, Ne. qr., Nw. ¼.) On the opposite side of the river it has yielded gently to erosion and good exposures do not occur, though its presence may occasionally be detected for some distance both up and down the river. At the upper, west, end of the exposure the stone is abruptly replaced by twenty feet of Saint Louis limestone covered by coal measure shales containing a small coal seam which has been mined at one or two points. The contact between the sandstone and the shale is such as to indicate that the former occupies an erosive channel in the latter which has cut down

through the shale and into the underlying Saint Louis. Immediately west of where the wagon bridge crosses Cedar (Tp. 75 N., R. XVII W., sec. 3, Ne. qr., Se. ¼) this bed of shale is seen to rest unconformably upon the Saint Louis as represented in figure 34,

The Saint Louis is here represented by about twenty feet of sandstone, much more regular in character than that shown above the Bellefountaine ford (see figure) and which is doubtless its equivalent. Resting on this sandstone is about four feet of compact grey to buff limestone such as is most characteristic of the Saint Louis of this region. Cutting down into both the limestone and the sandstone below the surface of the water, is a channel which has been filled with a dark clay or shale twenty to thirty feet in thickness. Running through this is a bed of highly bituminous shale or impure coal. The latter is quite irregular and rises quite rapidly toward the east where it is four feet in thickness. Toward the west it thins out to about eighteen inches, rising over the limestone. This coaly layer is covered by thirty to forty feet of argillaceous and sandy shale. The coal seam may be traced down to within a few feet of the Raven Cliff sandstone and is abruptly cut off by the latter. It is thus evident that there are two unconformities here. One between the limestone and the coal, the general unconformity between the Des Moines beds and the Saint Louis, and the other marking an erosive period later than the formation of the coal and of sufficient extent and duration to cut down and entirely through it.

An examination of the section preceding, as well as those given on succeeding pages, will show at once that the coal measures of Mahaska county are most largely composed of shale. Shales of two general types are usually encountered. The most common is the bituminous shale, a black fissile form known among the miners as slate. The second form is the argillaceous shale which is usually not so fissile, and is found in all colors, dark and drab to grey predominating. These shales are most frequently known among miners as soapstone. The fire clay found under the coal is usually a modification of the latter, being the upper few feet which served as a

soil to the coal plants when growing. As a result certain chemical changes have taken place, consisting principally of a loss of alkalies and iron, rendering the clay available for refractory purposes. This change does not usually affect more than the upper portion, and the lower part of a thick bed is indistinguishable from the ordinary grey clay shale. Arenaceous or sandy shales are common in coal measures of the Des Moines age, but do not in this county form so prominent a portion of the whole as either the bituminous or argillaceous shales. When encountered the sand content is usually relatively small.

PLEISTOCENE.

Covering the indurated rocks of the Carboniferous is a thick series of unconsolidated materials of much later origin. They are divided into three more or less distinct divisions, the drift, loess and alluvium.

DRIFT.

The drift deposits cover the entire area of the county. They consist here, as elsewhere, of till, gravel, sand, and clay. The till is more widely and generally distributed than either of the other constituents of the drift, and consists of fine yellow clay through which is scattered pebbles and erratic boulders of various sizes. It is seen in nearly every road side cutting and along all the streams.

A blue boulder clay is frequently encountered but does not seem to be so widespread as the yellow clay. When found it is lower than the latter. It has been found filling a preglacial gorge in the Excelsior mines, and here contains frequent pebbles, bits of coal and sticks of wood.

Sands and gravels, while found in the drift, rarely form large beds. Their greater development is along the flood plains of the modern rivers. Eddyville is built upon such a flood plain, the base being an approximately level bench of Saint Louis limestone which is covered by fifteen to twenty feet of loose sand and gravel. The latter has been dug for some time for railway ballast.

Glacial Scorings. The direction of the ice flow over northeastern Iowa has been determined by McGee, and Keyes has

recently summarized the observations on glacial striæ throughout the state. It is of interest to note here that just outside of Mahaska county such striæ have recently been found. Opposite Eddyville, as has been said, the Saint Louis limestone is extensively exposed. It has been quarried at several points. A recently opened quarry showed the stone directly covered by the coarse pebbly clay of the drift. At one or two points there were small patches of the limestone which showed the carving action of the ice. The direction of most of these striæ was S. 42° E. These striæ were, at one point, cut into and across by a later set running S. 70° E.

LOESS.

The loess is frequently encountered resting on the till. An interesting section, showing the relations between the two, is exposed on North Skunk river. (See page 325.)

The loess covers the uplands and has been used at New Sharon and Lacey in clay work. It is more usually found in an altered form, having largely lost its porosity and become more clay-like. There are slight differences in the amount of sand content found at different depths. It very frequently shows an apparent merging below into the yellow clay.

ALLUVIUM.

Alluvial matter is here as elsewhere developed along the principal streams. It consists of the usual dark loamy soil covering the flood plains. Its distribution along the major streams may be inferred from the map showing the extent of the Saint Louis areas in the county since both are practically confined to the bottom lands. There is the important difference however that the Saint Louis only underlies a portion of the bottoms while the alluvium covers all these areas.

Wind Blown Sands.—About two miles southeast of Peoria (Tp. 77 N., R. XVI W., sec. 26) is an interesting ridge of moving sand. It is about thirty feet high and a half mile or more long with a northwest to southeast trend. The sand is loose, fine, and coarsely stratified. It has a motion toward the northeast which has made necessary the removal of several houses which

stood in its path. The sand has covered up several fences and where the road now crosses the ridge the third fence in vertical succession has been put up. The motion has finally been stopped by a grove of trees in its path.

The explanation of the phenomena is not difficult. The combined valleys of the Skunk river and Buckley creek here form a broad bottom land which is bounded by drift hills. These on the east side of the valley have a northwest to southeast trend. Being made up of loose unconsolidated strata and exposed to the prevailing winds from the southwest which sweep across the wide bottom lands, the finer sands on the top of the hill have become ridged up and are driven forward by the wind. While most of the material is doubtless taken from the hill upon which the sand ridge rests, it is not improbable that a considerable portion is deposited by the wind itself which sweeps across the bottom land and when checked by contact with the ridge drops a portion of its load.

Geological Structure.

CROSS SECTIONS.

Harvey to Eddyville (figure 1, plate ix). Near Harvey, just west of the Mahaska county line, the Saint Louis rises to an elevation about equal to that of the railway station at that place, or 718 feet. North and west of here it is covered by seventy-five feet of shale which are in turn seen to be overlain by the Redrock sandstone. South and east the shales are present and contain a seam of coal. The Redrock is not seen below Harvey. At Bellefountaine the middle Saint Louis or Verdi beds are exposed, the heavy sandstone member being finely cross-bedded (see figure 35). Near the mouth of Coal creek, and at other points, the limestone is seen to be overlain by coal measures, as also opposite Eddyville. At the latter place the Saint Louis rises seventy feet above the water. The fall of the river between Harvey and Eddyville is about fifty feet, so that the Saint Louis reaches about the same level at both points.

Along Skunk River (figure 5, plate ix). Near the mouth of Thunder creek, in Marion county, the Saint Louis rises twenty-five to thirty feet above the water, the massive sandstone layers showing that the beds belong to the Verdi. Near Peoria, and south of there on the river, the beds of the upper or Pella division are seen. For some distance southeast from this point no good exposures are found. At the city water works north of Oskaloosa the Pella beds are again exposed, being covered by the black shale of the coal measures. The Saint Louis from this point is exposed almost continuously down to Currier's mill. It forms a well defined terrace about twenty feet above the river. Near the mouth of Spring creek the lower portion is seen to be made up in part of the heavy sandstones of the Verdi.

At Currier's mill the limestone is abruptly cut out, and a bed of sandstone and shale takes its place. This extends only a short distance along the river when the limestone again appears. Through White Oak township the limestone contains thick layers of heavily cross-bedded sandstone, and may be referred to the Verdi. Near the east county line, at one place, a small basin has been excavated in the Saint Louis and is filled in with shale containing a thin coal seam which has been, to some extent, worked.

Atwood to North Skunk (figure 3, plate ix). A mile south of where the North Skunk crosses the county line, the Des Moines beds are seen to overlie the Saint Louis. Southeast from here the only exposures seen belong to the coal measures until Union Mills is reached, where the Saint Louis reappears. It is exposed for some distance along the river, being covered at times by black shale (Tp. 77 N., R. XV W., sec. 26, Se. qr.) and other coal measure strata. At one point (Tp. 77 N., R. XIV W., sec. 30, Sw. qr.) both the Des Moines beds and Saint Louis are cut through by a channel now filled in with drift. At both the Roberts and the McBride mills the limestone is interbedded with sandstone bands. At the latter place the upper layers of the formation also appear with their characteristic fossils.

At the Columbia mine the Saint Louis is again cut out and replaced by the Des Moines beds which extend along the river

nearly three miles. The limestone ledge again appears a mile or more above Atwood. Between North Skunk and Atwood the river falls nearly sixty feet. The top of the Saint Louis at Atwood is twenty feet or more below that at North Skunk, a difference that seems to be due wholly to erosion.

North Skunk to Eddyville (figure 4, plate ix.) At North Skunk the Saint Louis is covered by twenty-five feet of coal measure shale, above which is a sandstone exposed on the railway north of New Sharon. It is seen here to be twelve feet thick and its total thickness is probably not far from twenty-five feet. Nothing but drift is seen between New Sharon and the South Skunk river. At the latter point the Saint Louis is again seen to be covered by shale. At Oskaloosa the Saint Louis is about 125 feet below the surface, the upper sixty feet of this distance being drift and the remainder being beds of the Des Moines stage. At Given the limestone is probably not more than twenty feet below the bed of the Muchakinock. It is exposed in the banks of the stream a short distance south of here and rises in the hills twenty feet or more above the railway track near Eddyville.

Atwood to Harvey (figure 2, plate ix.) Along this line the Saint Louis is exposed at Atwood, south of Rose Hill and at Harvey. Between these points the coal measures are covered by drift. At Oskaloosa the coal lies about 110 feet below the surface, or at an altitude of 733 feet. At Evans it is about fifteen feet below the railway or 728 feet above sea level. Near Rose Hill it lies at about 720 feet, and at other points at about the same level.

DEFORMATIONS.

The structure of Mahaska county is quite simple. The rocks have a gentle dip to the southwest in common with those of the entire state. In the beds of the Des Moines formation local dips in various directions are found, but these are due usually to the slight differences in level brought about during the settling coincident with the solidification of the strata.

The county has been singularly free from disturbances since the deposition of the rocks and the exposures present are due entirely to erosion. The differences in altitude occasionally

noted between different outcrops of the same formation may be referred in nearly every instance to unconformities of erosion.

No deformations of any great extent have been found in the county. McGee in his work on northeastern Iowa has traced several slight anticlinals and synclinals having a general northwest to southeast direction. He thought he found evidence of one or two running parallel to these and crossing Mahaska county. One of these was called the Skunk river and the other the Des Moines anticlinal between which lay Oskaloosa synclinal. Speaking of the latter anticlinal he says: "The Des Moines river unquestionably follows the crest or southwestern slope of a gentler anticlinal by which the sub-carboniferous rocks are brought, not only to the surface, but well up in the bordering bluffs from the central part of Marion county nearly to the extreme eastern corner of the state"*.

So far as Mahaska county is concerned no evidence has so far been found confirmatory of these observations. As has been shown the Saint Louis limestone is exposed along both the Des Moines and the Skunk rivers. While its surface is, in consequence of the profound pre-coal measure erosion to which it has been subjected, quite irregular, it still lies at about the same level throughout the county where exposed.

A line drawn from Atwood to Harvey would cross, though not directly, the Skunk river anticlinal, the Oskaloosa synclinal and the Des Moines river anticlinal. Fortunately the levels along this line are at hand, being taken from the Chicago, Rock Island & Pacific railway. According to this authority Atwood is 721 feet above sea level. Just east of the station the Saint Louis rises ten to twenty feet above the track. At the point where the railway crosses South Skunk the Saint Louis is replaced by coal measures, but a short distance below is seen to lie at about the same level as the track, 718 feet. The coal at Oskaloosa, at the Long mine, lies about ninety feet below the track. This coal belongs to the horizon formerly worked at the old Standard mine where it was found to lie about twenty feet

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*Pleistocene History of Northeastern Iowa, Eleventh Annual Report, U. S. Geol. Sur., pt. I, p. 341. Washington, 1892.

above the limestone. This would make the elevation of the Saint Louis at Oskaloosa nearly 733 feet. Other borings in the neighborhood confirm this estimate. At Evans the coal lies at 728 feet and the limestone is known to be not far beneath. At Harvey the limestone is on nearly the same level as the track, or 718 feet, though at Durham and Flaglers it is slightly higher.

A comparison of these levels shows that the total variation in elevation is not greater than that known to be due at numerous points to erosion alone. A number of the deeper mines near Oskaloosa have been carefully connected by barometer levels, and in each case their greater depth was found to be amply accounted for by the greater elevation of the mouth of the shaft. The coal all lies at about the same general level and the differences in the level at which it is reached, are due to the modern topographic features of the region.

While no evidence can be found of a series of deformations running from northwest to southeast, there is some slight evidence of a series running at right angles to that direction. Owen, as early as 1852, called attention to certain evidence of an anticlinal crossed by the Des Moines near Bellefountaine*. The greater part of the difference in elevation noticed here is again due to erosion. In view, however, of the fact that the Saint Louis exposed here consists of the alternating lime and sandstone layers characteristic of the middle part of that formation, while at Harvey above, and at the east end of the Raven Cliff exposure below, the exposures are of the upper fossil-bearing ledges, it is not improbable that a slight anticlinal is in reality present. This appears more probable when exactly similar phenomena are observed on South Skunk, near the mouth of Thunder creek, and on North Skunk near both the Roberts and the McBride mills.

These deformations do not appear to be of great extent and in Mahaska county cannot be directly connected with one another. In Keokuk county to the east similar deformations have been noted and traced across the county.

*Geol. Sur. Wis., Iowa and Minn., p. 115. Philadelphia, 1852.

UNCONFORMITIES.

Two widespread unconformities occur within the strata of the county, and several local unconformities mark time breaks of less extent.

UNCONFORMITY BETWEEN SAINT LOUIS AND DES MOINES STAGES.

The first erosive interval of which we have any record in this county is that which succeeded the deposition of the Saint Louis strata. The time intervening between the Saint Louis and the Des Moines stages and represented further southward by the Kaskaskia deposits of Missouri, is throughout Iowa a period of erosion rather than of deposition. The Saint Louis beds were raised to a considerable elevation above the sea; the waters retreated south and west; a drainage system was developed and the continent was gradually carved into topographic forms not greatly different from those now found.

After a period of time, of the length of which we have no guides for measurement, the land again sank beneath the encroaching waters and the shore deposits of the lower coal measures filled up the irregularities of the old surface. Naturally enough the first deposits laid down in the new series were the coarser sandstones and shales. The former are more usually found filling the irregularities of the old surface, as near the Columbia mine. At Currier's mill sandstone is interstratified with shale, and near the mouth of Cedar creek shale alone is seen. As the conditions became more stable the finer shales and coal seams were formed over these earlier beds.

This unconformity has been noticed by many workers and carefully studied. There are probably no places where it is shown to better advantage than at the localities already mentioned. (See figure 34.)

RAVEN CLIFF UNCONFORMITY.

Local unconformities in the coal measures themselves are by no means uncommon. They have been found at many points and are occasionally encountered in mining. Keyes* has called attention to a profound erosion immediately subsequent to the deposition of the Red Rock sandstone. The Raven

*Stratigraphy of the Carboniferous in Central Iowa, Bul. Geol. Soc. America, II, 277-292. 1891.

Cliff sandstone seems to have been deposited after a similar, if not the same, period of erosion. The argument for its unconformability has already been stated. Its relations to the Red Rock sandstone do not seem to be close. The latter rests apparently conformably upon a series of coal-bearing shales seventy-five feet thick which are unconformable upon the Saint Louis. They may be traced down the river to Raven Cliff where the Raven Cliff sandstone is seen to rest unconformably upon the lower portion of these shales. The Raven Cliff sandstone is then, later than the Red Rock and probably contemporaneous with the coal seam which is unconformable upon the latter. The Raven Cliff sandstone is the latest member of the Des Moines formation found in Mahaska county and cuts through a bed of shales which is apparently connected with those found above the Currier's mill sandstone. The Raven Cliff Rock does not appear to cover any large area. It may be traced on the east side of the river for a few miles but has not been encountered in the mining operations near Evans and Beacon. It seems to have been a local deposit only and lay in a narrow channel cut through the coal measure into the limestone.

DRIFT AND INDURATED ROCKS.

The later widespread unconformity is that existing between the unconsolidated deposits of the Pleistocene and the indur-

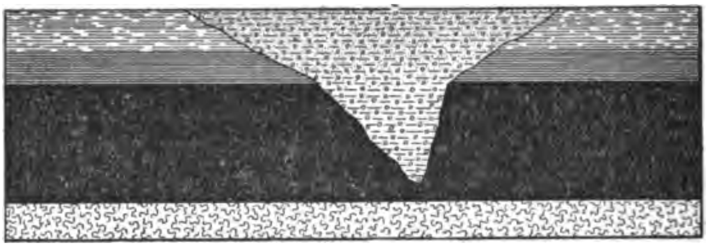
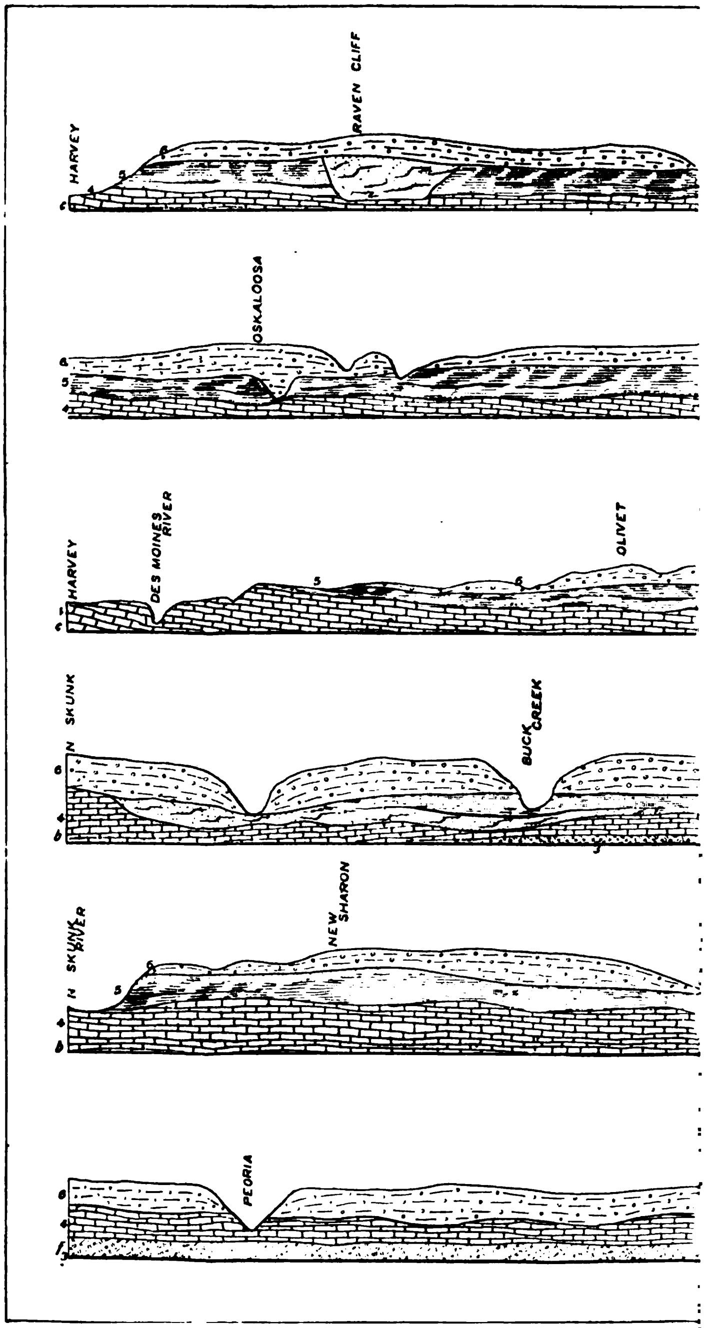


Figure 36. Drift channel in coal; Excelsior mine, Carbonado.

ated rocks below. During the period preceding the ice invasion this county suffered profound erosion by which a large proportion of the coal measures was carried away and deep channels cut in the remainder. These channels have been found at several points, but are not well enough known to allow the


HARVEY
RAVEN CLIFF
OSKALOOSA
HARVEY
DES MOINES RIVER
OLIVET
SKUNK
BUCK CREEK
SKUNK RIVER
NEW SHARON
PEORIA

reconstruction of the drainage system of that time. There is some evidence of a deep drift channel running under a part of Oskaloosa, and from there southeast to Fremont, though this has never been accurately traced. In the mines minor channels filled with blue clay containing gravel and wood, or with sand have been encountered at several points. One of the most interesting of these is seen in Excelsior No. 5, at Carbonado. Here in driving an entry such a channel was encountered running from northwest to southeast. It was found to be sixty feet wide at this point, while 300 feet distant, on a parallel entry it did not cut through the coal. The channel has sharp, clear cut sides and it is at one point V-shaped. (Figure 36.) At another the channel is very narrow, and it is filled with loose, red sand. The sides of the coal, as seen here, are polished in a manner suggestive of ice action.

These two major unconformities lie above and below the coal beds, and both are factors in the present limitation of available beds. The general relations of the strata are shown in figure 37, an ideal cross section of the county from northeast to southwest.

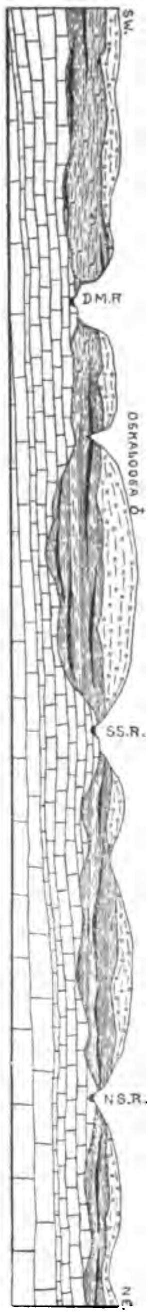


Figure 37. Ideal cross-section in Mahaska county.

EXPLANATION OF PLATE.

In plate ix the numbers refer to the various formations as follows: (1) Augusta, (2) Springvale, (3) Verdi, (4) Pella, (5) Des Moines, (6) Drift.

COAL.

MINES.

Mahaska county has long been the most productive coal county in the state. At present there are thirty mines in operation, about

half of the number being commercial or shipping mines with outputs of from 200 to 1,000 tons per day. The annual output for the county is considerably more than one million tons.

Mines are now operated in nine townships, but the mining industry is very irregularly distributed, a very large proportion of the coal being mined within a few miles of Oskaloosa, and the greater portion being obtained within the Muchakinock valley. The mines of the county may conveniently be considered in several groups more or less arbitrarily defined, yet on the whole having a natural basis for classification. These groups include the Buck Creek mines, Columbia mines, Rose Hill mines, Spring Creek mines, Oskaloosa mines, Leighton mines, Evans mines, Beacon mines, Muchakinock mines, Lost Creek mines, Cedar Creek mines and Coal Creek mines.

Buck creek mines. Buck creek is a small stream flowing southwest into the North Skunk river about three miles east of New Sharon. Both Buck creek and the North Skunk in this region flow over the drift which here directly overlies the coal measures. On the latter stream the Saint Louis is exposed within a few miles both above and below the mines, and probably lies at no great depth beneath the coal. Between these two outcrops of the limestone is a small basin in which coal measures occur and over a considerable area of which coal is known to be present. Mines are now being worked here at three points. The most northerly is the Evans mine, a slope located nearly within a mile of the north county line. Near by is the Smith mine and a half mile southward is the Williams opening, all operating in the same coal.

As seen at the latter place the coal is four and a half feet thick though it shows considerable variations and an average for the district would probably be nearer three and a half feet. The section at this mine is:

	FEET.	INCHES.
4. Shale, bituminous, fissile, below, with one-foot lime-rock band	14	
3. Coal	4	6
2. Fire clay, drab, variable in thickness from 0 to 5 feet	2	6
1. Sandstone, massive (exposed)	2	

Figure 38. Coal bed in Williams mine, near New Sharon.

The greatest thickness of coal known in this area is six feet, but as stated most of it is thinner. The coal is not greatly faulted, only an occasional small slip being found. It is slightly undulatory in character. The shale is usually, so far as known, of sufficient thickness to afford a good roof.

The mines so far opened in this region have all been small country banks so the extent of the seam is not known. At one point west of the river (Tp. 77 N., R. XV W., sec. 18, Se. qr.) coal has been mined which probably belongs to the same seam. If so the known area extends in an irregular northeast-southwest direction for a distance of three miles with a maximum width of one and a half miles.

Columbia mines.—These mines, which include the two shafts of the Columbia Coal Company and a local mine, are located in the extreme southeast corner of Monroe township a short distance north of Atwood. The Columbia mines have a switch from the Chicago & Northwestern railway, but the other mine is operated for local trade only. A section of the strata at this point has already been given. The basal sandstone seen here has been traced some little distance south and west and is known to attain a considerable thickness.

The details of the section through the coal are as follows:

		FEET.
5.	Blue clay	4
4.	Shale, dark colored, variable thickness	2
3.	Coal, containing some clay-ironstone	6
2.	Fire clay	3
1.	Sandstone, light colored, rather massive (exposed in road near by)	15

Figure 39. Seam of coal in Columbia shaft. Rose Hill.

This coal shows the usual variations with regard to position and thickness. Over a considerable portion of the area of known coal the shale roof has been cut away and a stiff blue clay laid down upon it. This is not suitable for a roof, and hence only a limited amount of the coal can be removed. Its total extent is not known. The coal measure may be traced some distance up the river as indicated by the presence of shale at one or two points. Prospect holes also reveal the presence of coal measure shales on sections 20 and 30 of the adjoining township in Keokuk county (Tp. 76 N., R. XIV W.) though no workable coal is known to exist nearer in that direction than the What Cheer mines. It is not probable that the Columbia coal extends over more than a limited area.

Rose Hill mines.—The mines near this place do not strictly belong to one group, but may be conveniently grouped together under a single heading. Three miles northwest of Rose Hill is the Bacon mine, now operated by Michael Carey. The coal found here is stratigraphically above the coal measure sandstone exposed at Currier's mill. It is five and one-half to seven and a half feet in thickness. There is a slight difference in the quality of the upper and lower coal, the upper appearing brighter and heavier though there is no true parting. The roof is a dark shale of good quality throughout. About one mile west (Tp. 75 N., R. XV W., sec. 1, Nw. qr.) a coal believed to belong to the same seam was formerly mined.

Four miles southwest of Rose Hill and on the opposite side of the river, coal has also been mined some distance back from the river. The Bolton mine, located at this point, is worked in a coal occupying a position but little above the Saint Louis. The section of the shaft shows:

		FEET.
4.	Drift	30
3.	Shale, bituminous	25
2.	Coal	3½
1.	Fire clay	

The exact distance intervening between the coal and the limestone has not been ascertained. A mile and a half northeast of the Bolton mine (Tp. 75 N., R. XIV W., sec. 16, Sw. qr.) coal presumably of the same horizon was formerly reached by a drift driven in from the river. A short distance east of this drift at the bridge south of Rose Hill, the limestone appears, as well as in the hills opposite this old mine.

Seven miles southeast of Rose Hill, or four miles north of Fremont there is a small coal measure area. The coal is twenty-two inches thick and is covered by about twelve feet of shale, the whole occupying a narrow gorge gouged out of the Saint Louis. The coal is reached by a drift, and only one small mine, the Howell, is in operation. The coal measures extend for a half mile or less along the south bank of the river, but do not appear on the north side.

The coal apparently has only a limited extent as the Quarton prospect shaft, a short distance northeast of Fremont, showed hardly enough coal to be distinguished from the shale. The section passed through by that shaft was as follows:

		FEET.
5.	Drift, sand, gravel and clays	70
4.	Shale, black, fissile, coaly below	8
3.	Fire clay	2.
2.	Shale, grey, indurated, somewhat sandy	10
1.	Saint Louis limestone, fossiliferous	30

Spring creek mines.—About two miles northeast of Oskaloosa at Carbonado is a group of mines including shafts 4 and 5 of the Excelsior Coal Company and the Hoover mine. These all

work the same coal which lies at a depth of about 15 to 90 feet below the general level of the country. The Excelsior mines ship over a switch from the Iowa Central railroad and have been in operation for five years. Before they were opened the company operated mines in the Muchakinock valley. The Hoover mine is older and takes coal from territory completely surrounded by that of the Excelsior Coal Company. It is operated for local trade.

The following measurements represent the average details of the beds:

		FEET.
4.	Shale, argillaceous, grey; with some plant remains	10
3.	Shale, bituminous, fissile; with many plant remains	1½
2.	Coal	6
1.	Fire clay, exposed	3

The coal is of good quality and presents usually a good workable thickness. It shows considerable variation in altitude, this variation being in places, so rapid as to make the haulage difficult. A tail rope is used on the main haulage ways in the Excelsior mines. The roof has been badly weakened by erosion, and in places is entirely cut away. The drift channel encountered here has been already described.

Southwest of the Carbonado mines and within the limits of the city is the Economy mine which takes coal from a depth of eighty feet. The coal is four and a half to five and a half feet in thickness and covered by thirty-five feet of grey shale. Near this mine in the pit of the Oskaloosa Paving Brick Company a coal seam is exposed which is doubtless a continuation of that at the Economy mine. The coal at these two points serves as a connecting link between the coal of the Spring creek and Oskaloosa districts. Though the coal of these districts is probably not now directly connected, it is not unlikely that at one time it was and that the separation is due to later erosion.

Oskaloosa mines.—While there are places under Oskaloosa where coal has been cut away or is only thin and of poor quality the greater part of the city is built over a good coal bed. A number of small mines were formerly operated just north of town, but these are all abandoned. South and west of the city good coal is mined at several points.

The Long Brothers Coal and Mining Company operate a mine in the southern part of the city. They have a switch from the Burlington & Western railway and also ship on the Chicago, Rock Island & Pacific.

The coal lies at a depth of 110 feet. It varies in thickness up to eight feet, the average being from six to six and a half. It is usually quite level, the undulations being neither rapid nor great in total variation. A washout north and west of the shaft has been traced some distance. The coal found at the Long mine is probably identical with that exposed at the Guthrie brick yard and mined at several points near there. The mines now working it are small and supply a local trade only, though formerly some of the large and important mines, including the Acme and Standard (Tp. 75 N., R. XVI W., sec. 14, Se. qr.) obtained coal from this horizon.

The mines now working include the McFay and Cook slope where the coal is four feet four inches thick, the Andrews mine, a shallow shaft having coal varying from three and a half to five feet thick, and the Guthrie mine sixty feet deep and with coal from five to seven feet thick, all located north of the Chicago, Rock Island & Pacific railway. Between the main line and the Beacon cut-off track are two small mines. At Logue's mine, a shaft, the section shows:

		FEET.
3.	Drift	16
2.	Shale, bituminous	20
1.	Coal	3 to 4

This coal is also reached by a slope just south of this mine and may be a higher seam than that met in the others, though more probably, it is the same. In the same section is Mine No. 1, of the Oskaloosa Coal Company located on a switch from the Iowa Central railroad. The coal is here from six to seven feet in thickness and is reached at a depth of eighty feet.

Leighton mines.—The mines of this and the succeeding groups with the exception of the Cedar Creek and Coal Creek mines all fall within the Muchakinock valley and to a certain extent belong together. Inasmuch, however, as they are not known to constitute a continuous coal seam, but rather are

known in many cases to be discontinuous and to belong to different basins, it seems best to consider them separately.

The coal near Leighton and Fishville lies near the surface and has been reached in part by drifts and slopes. The Davis mine, formerly known as the Leighton, is a shaft thirty feet deep with coal five feet in thickness and with a good hard roof. Near this mine are a number of abandoned drifts formerly known as the Hoover mines. The Patterson mine, southwest of the Davis, is seventy-six feet deep and works in coal four and a half to five feet thick. Near the Fishville station is Fishville mine No. 2, a shaft fifty feet deep. The section exposed in this mine is:

		FEET.
3.	Shale, dark gray, exposed	5
2.	Coal	3½ to 5½
1.	Fire clay, exposed	2

Evans mines.—The American mine, located a half mile west of the railway station on the Chicago, Rock Island & Pacific railway, is one of the largest mines in the state. It has been in operation fifteen years, in which time the workings have extended south nearly two miles. The coal is hauled to the foot of the slope in trains of twelve to fifteen cars by a continuous rope and is there hoisted to the dump in trains of six cars by an independent rope. The main hauling is done on two parallel entries one for ingoing and the other for outgoing cars.

A bore hole near the mine (Tp. 75, N., R. XVI W., sec. 18, Sw. qr.) showed the following strata:

		FEET.	INCHES.
6.	Drift	18	
5.	Shale, grey	8	
4.	Coal	1	
3.	Shale, grey	25	
2.	Shale, bituminous	47	
1.	Coal	6	2

The coal is reached at the mine by a slope and lies about fifteen feet below the railway, or at an altitude of about 728 feet. It varies in thickness from five to seven feet or more but averages a little over six feet. A section measured as follows:

	FEET.	INCHES.
4. Shale, grey, somewhat fissile, often banded in layers of grey and white, exposed	4	
3. Coal, often with a local development of a four-inch cannel-like layer in the lower part		10
2. Shale, black, bituminous, fissile, many coal plants		3
1. Fire clay, white, exposed	3	

The parting shown here is not always present, being in fact usually absent. It consists of a hard cannel-like layer, which while having the appearance of bony coal really burns as well as the remainder. Ironstone nodules and bands occur in parts of the mine, being usually found near the top of the seam. There occurs at one point a mass of this material twelve feet in length and two feet in thickness.

A number of small faults have been found in the mine one being represented in figure 38, where the line of movement in passing through an irregular band of ironstone has been deflected from its course. The American Mine now only takes

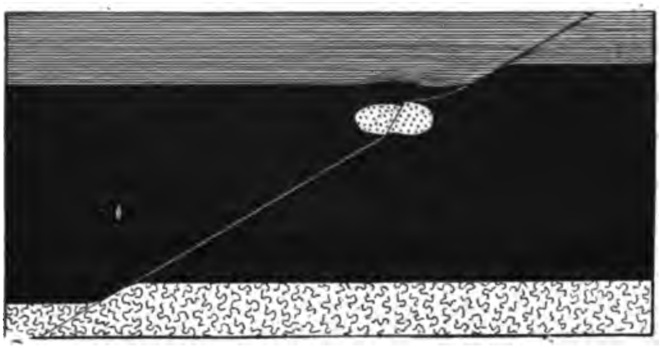


Figure 40. Fault in American mine. Evans. Line of slip passing through ironstone.

out coal from south of the railway, but it is expected soon to open up territory lying immediately north of the present opening.

Near Olivet some coal has been mined for local purposes and a mile and a half south of Evans is the Hull mine also supplying local trade.

Beacon mines.—Coal has been extensively mined in this vicinity for many years and there is a considerable number of

abandoned mines. Those which are now working belong in reality to three groups of two each. How closely the coal of these different groups is connected can not now be stated. It is more than probable that areas of low coal separate them.

The Garfield Coal Company operates a slope mine about one mile west of Beacon station using tail rope haulage and shipping on the Chicago, Rock Island & Pacific. The section as measured in the mine is:

		FEET.	INCHES.
4.	Shale, bituminous, with fossils in pyrite, full thickness 30 to 40 feet; exposed	8	
3.	Coal	5	2
2.	Fire clay	2	
1.	Fire clay with considerable grit	1	

The coal shows the usual variation in thickness, but the above section is a fair average. At one point the coal is divided by a layer of shale as shown in the accompanying figure,

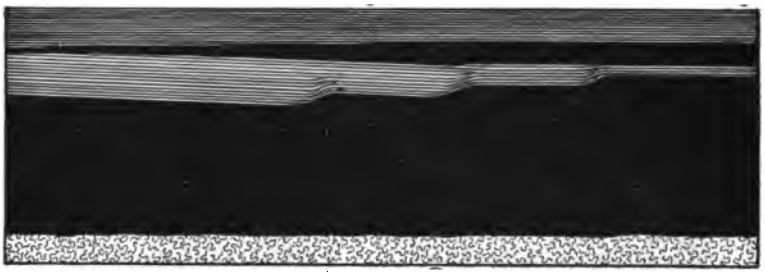


Figure 41. Shale bands in coal seam. Garfield Mine, Beacon.

which probably represents an incursion of sediment during the formation of the coal. An impure limerock containing brackish water forms, occasionally makes its appearance above the coal. The Beacon Coal Company operates a small slope near the station.

There is a small stream flowing into the Muchakinock from the northwest just below Beacon. A spur from the Chicago, Rock Island & Pacific railway has been built up this stream. On it are located the Green mine and the Oskaloosa No. 2, about two miles west of the station. The coal at the two mines is essentially the same, running up in places to seven and a half

feet in thickness with an average of about six feet. It has the usual black shale roof, here quite fossiliferous.

A mile and a half south of Beacon is an area of coal which is being opened up by two mines, the Consolidation No. 8 and Oskaloosa No. 3, both having connection with the Chicago, Rock Island & Pacific and both having been recently opened. The section of the former has already been given and that at the other does not differ essentially. The coal in this basin is marked by greater irregularities in position and thickness than that worked farther east. The presence of impure limestone or "hydraulic rock" is more frequent; six feet of this rock being found immediately over the coal at the Oskaloosa shaft. In the Consolidation No. 8, the usual number of small faults and rolls is found. There are also two points at which the action of underground water is shown in cutting out the strata below, probably in part the Saint Louis, which is known here to be not far below the coal, and allowing the coal to be crushed down into the depression. The phenomena are identical in all particulars with those seen in limestone countries and known as sink holes. At one point in the mine such a hole twenty-one feet in diameter was encountered. The fire clay had washed down into it and the coal above had in part given way. The passage was sufficiently clear to act as a drain. At another point the coal has given way beneath the pressure and the area is now one of loose, finely broken or crushed coal, with fine calcite seams.

The upper coal seam is exposed in the ravine near Mine No. 8. It is here quite thin as shown in following section:

	FEET.
3. Limestone, impure, bituminous	$1\frac{1}{4}$
2. Coal	1
1. Sandstone, exposed	4

Muchakinock mines.—The mines formerly located at Muchakinock have been worked out and abandoned, the newer mines being located farther north. The greater part of the area underlaid by the Muchakinock coal has already been exhausted as it has been worked as heavily as any coal in the state. In addition to the Consolidation mines, the old Excelsior mines drew

their supply from this basin. The coal lies in an irregular area about two and one-half miles east and west by three and a quarter north and south. Its eastern limit is just beyond the mine of the Iowa Fuel Company at Colon, and its northern runs just north of the Consolidation mines 6 and 7. The coal does not connect directly with that of the other basins, low coal shales and "hydraulic" rock occupying its place along the dividing lines. The bed lies at a general elevation of thirty feet above the underlying limestone with fire clay, graduating below into shales, between. The upper coal is usually found wherever the cover is sufficient to have protected it. It varies in thickness from one to four feet, but it is poor quality and of no value.

There are three mines now working in this basin all being large and well equipped and having connection with the Chicago & Northwestern railway. They are Consolidation No. 6, Consolidation No. 7 and Iowa Fuel Company. At the first the section passed through by the shaft was:

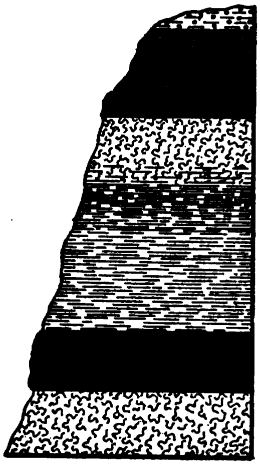
		FEET.
6.	Drift	70
5.	Shale, grey, argillaceous	28½
4.	Coal	2
3.	Sandstone	3½
2.	Shale, bituminous	40
1.	Coal	7

At No. 7 the shaft is not so deep and the strata over the black shale have been cut away, drift taking its place. At the mine of the Iowa Fuel Company the "hydraulic rock" forms the roof over a part of the mine. This overlies the coal for a distance of 150 feet from the shaft. The coal varies from four to six and a half feet in thickness. A section measured in the mine showed:

		FEET.
3.	Shale, bituminous	1½
2.	Coal with occasional pyrite near the middle of the seam	5½
1.	Fire clay, exposed	2

West of Given is a small coal area distinct from that of Muchakinock yet closely related to it. Formerly a considerable number of mines were operated in it, but now the Griffith,

a local mine, is the only one running. The bluff near the Griffith mine shows the following:



		FEET.
6.	Soil	1
5.	Shale, dark grey, somewhat fissile	3
4.	Coal	1
3.	Fire clay, and clay shale	10
2.	Coal	3
1.	Fire clay (exposed)	3

Figure 42. Bluff at Griffith drift; Given.

Lost creek mines.—Southeast of the Muchakinock mining district is one from which considerable coal has been taken. The mines along Lost creek itself were small local mines and are not now worked. The principal mine now in operation is the Pekay mine of the Whitebreast Fuel Company. This is located on a branch of the Iowa Southern railway connecting at Pekay junction with the Iowa Central. The coal here varies from four and a half to six feet in thickness one section showing:

		FEET.
3.	Shale, dark colored, greatest thickness observed	8
2.	Coal, normal thickness	6
1.	Fire clay and light colored shale (exposed in entry below fault)	9

A "hydraulic rock" occurs over the slate in places and frequently comes down close to the coal.

The coal outcrops on the creek west of the mine. It forms a separate basin being cut off from the coal north and west by the usual poor coal and hydraulic rock. The area east shows thin coal in pockets, the better portion of the field running off to the southeast.

Figure 43. Fold and step-fault at Pekay mine.

An interesting step fault occurs in the main entry near the shaft. In a distance of twenty-five yards going south the strata rise nine feet. Then there is a fault having a throw of about two feet. Five yards farther on there is a drop of five feet. From this point the strata gradually fall by a series of flexures, reaching to the level of the track in a distance of twelve yards. Northwest of the Pekay mine is the Perkins, a small local mine. About three miles north of Eddyville prospecting has shown the presence of an area of thick coal in which a mine is to be opened at once. It will be connected with the Iowa Central railway by a spur.

Cedar creek mines.—Near the mouth of Cedar creek is a small seam of coal as already mentioned. This has been worked for local purposes at one or two points near Tracy. The Hallowell and Ream mines, working only in the winter, obtain coal from this seam.

Coal creek mines.—In the area southwest of the Des Moines river but little coal mining has been done, the absence of a railway probably being the main retarding cause. Along Coal creek shale and coal outcrop at numerous points. Near Eveland postoffice an impure coal seam ten feet thick shows in the creek. The section here is:

		FEET.
3.	Sandstone, shaly	12
2.	Coal, impure, shaly	10
1.	Fire clay, seen in mine	3

A drift, the Richardson, is operated in this coal. Of the whole section exposed barely four feet are worth mining and of this a

considerably less amount is really valuable. Other mines have at times been operated near here.

Figure 44. Coal near Eveland.

COAL LANDS.

The territory in the southwest has been in part prospected by drilling and is known to contain considerable thick coal which, however, lies as usual in irregular basins of small extent. A considerable amount of it can be profitably mined, 200 acres now being held by one company. A large proportion will however, never sustain anything larger than local mines. The Muchakinock valley has so far proven the most productive portion of the county. The lower part of the valley has been heavily worked and contains but little undeveloped territory. Farther north, between Evans and Pella, there are large areas of land which may prove productive. Thick coal is known to occur at one or two points. In the southeast the coal, so far as known, is thin and scattered. It is not improbable that considerable areas are not even underlain by coal measures but the facts are not known with sufficient accuracy to admit of

detailed mapping in this particular region. Between the two branches of the Skunk river, while prospecting has so far revealed the presence of thin coal only, thicker veins probably occur. In the northeast there are probably considerable areas of workable coal. The drift is thick and very little drilling has been done.

In general it may be stated that all the area marked on the map as Des Moines is legitimate ground for prospecting, though only a part of it will ever be found to contain workable coal. The exact limits of the individual coal basins can only be determined by thorough prospecting with the drill.

Mahaska County Mines.

NAME	Township N.	Range W.	Section.	Quarter	¼
American	75	XVI	18	Nw	Ne
Andrews	75	XVI	14	Sw	Se
Bacon	75	XIV	6	Nw	Ne
Bolton	75	XIV	20	Sw	Ne
Carbonado 4	75	XV	8	Sw	Ne
Carbonado 5	75	XV	8	Sw	Se
Columbia	76	XIV	36	Ne	Sw
Consolidation 6	75	XVI	36	Nw	Ne
Consolidation 7	75	XVI	36	Ne	Ne
Consolidation 8	75	XVI	34	Sw	Sw
Davis	75	XVI	1	Sw	Nw
Economy	75	XV	18	Ne	Sw
Evans	77	XV	8	Ne	S½
Fishville	75	XVI	12	Ne	Ne
Garfield	75	XVI	22	Sw	Se
Green	75	XVI	28	Ne	Ne
Guthrie	75	XVI	13	Ne	Nw
Hoover	75	XV	8	Ne	Sw
Howell	75	XIV	36	Nw	Ne
Iowa Fuel Company	75	XV	31	Ne	Ne
Logue	75	XVI	23	Ne	Nw
Long	75	XVI	24	Ne	Ne
McFay	75	XVI	14	Sw	Se
Oskaloosa 1	75	XVI	23	Se	Nw
Oskaloosa 2	75	XVI	28	Ne	Nw
Oskaloosa 3	75	XVI	34	Se	Ne
Patterson	75	XVII	2	Se	Se
Pekay	74	XV	20	Nw	Nw
Perkins	74	XV	19	Ne	Nw
Ream	75	XVII	32	Ne	Nw
Richardson	74	XVII	10	Sw	Se
Smith	77	XV	9	Ne	Sw
Tompson	74	XV	18	Sw	Sw
Williams	77	XV	9	Sw	Nw

CLAYS.

DISTRIBUTION AND CHARACTER.

Mahaska county is well supplied with excellent material for the manufacture of clay products. The coal measures, drift and the alluvial deposits all furnish material of considerable value. As has been explained the coal measures practically underlie the entire county. They are made up to a very considerable extent of shales. These shales have three type forms, arenaceous shales, bituminous shales and argillaceous shales, with an infinite variety of inter-forms. The arenaceous or sandy shale grades on the one hand imperceptibly into solid sandstone, and on the other into argillaceous, or clay shales. Rarely it grades directly into the bituminous form. The latter may become more and more bituminous until it becomes a bony coal from which the transition into good coal is often seen. It may on the other hand lose its bituminous content and become an argillaceous shale. The latter is the form in which the great mass of the coal measure shales of the region occur, the others representing exceptional developments or facies. It is also the form valuable in clay work. The others can not be used alone and only to a limited extent in connection with clay shales. The latter are usually drab to blue in color, though the most brilliant colors, such as red and yellow are also found. Clay shale occurs in beds of considerable thickness all through the coal measures and affords the best of material for common brick and tile, paving brick, sewer pipe and other coarser grades of clay ware. It is often of considerable purity and adapted to the manufacture of various forms of pottery. This grade of clay when found in close connection with the coal seams is known as fire clay. Not all of the material, however, known by that name in mining regions is of the same grade, and not all of it can be used for refractory wares. Nevertheless there are here abundant supplies of such material of excellent quality. It has so far only been used experimentally for local purposes.

The clays which are of glacial origin are found in the upper portion of the drift. Those which occur in the lower portion

are too impure for use. They belong to the till and are filled with gravel, sand and other impurities. The upper clays, which are found throughout the county covering the higher lands are probably derived from the loess by alteration. The upper portion is oxidized and altered into a soil. In this form it is used for the manufacture of hand-made brick exactly as alluvium is used. The greater portion of the clay is, however, taken from beneath this soil layer, a thickness of ten to twenty feet being usually available. This clay is drab to blue with blotches of yellow. It does not usually show stratification. Jointing is frequently developed. It exists in large quantities, in a pure state, is easily worked and burns to a good color. The chief difficulty to be encountered in its use is that of checking while drying. Great care must be used to prevent this. The clay will not dry rapidly and so far patent dry houses have been only measurably successful.

In addition to the two sources of material mentioned above there is a third. In this county as elsewhere the flood plains of the larger streams, and to some extent of the smaller streams also, are made up of alluvial material. This is the black, loose textured soil which covers the bottom lands. It has long been used for the manufacture of brick. It is everywhere available, easily worked, and makes a good grade of common brick.

CLAY INDUSTRIES.

NEW SHARON.

Martin and Burket have a new and well equipped plant at the north edge of town. The clay used belongs to the Pleistocene being the altered loess described above. It is mixed with about ten per cent of a soft coal measure sandstone which is ground and mixed with the clay. It is moulded on a Freese machine and dried in an Andrews dry house. This has a capacity of 28,000 brick, or 14,000 tile. The brick and tile are loaded on No. 70 Raymond cars at the machine and run directly into the dry shed. The brick drys in about five days and the tile in half as long. The product is burned in down draft kilns, being water-smoked two days. An excellent grade of both brick and tile with a good color is made.

Peter Meyers operates a small brick plant one and a half miles north of New Sharon. The clay now used is a drift clay similar to that used at the Martin and Burket factory. Coal measures also occur, and both shale and fire clay have been used experimentally with good results. The material is moulded on a Penfield machine, dried under open sheds, and burned in a down draft kiln.

LACEY.

Charles Hull manufactures brick and tile at this point, the factory being located on the Iowa Central railway at the north edge of town. The clay is of the usual character being taken from the loess. It is obtained from a railway cut near the factory. The clay is moulded on a Penfield machine and dried under closed sheds. It is burned in two down draft kilns. A center draft kiln is also used and has given excellent satisfaction. It burns the brick more evenly than the others.

BARNES CITY.

Just southeast of the depot is a brick yard. The clay is taken from a cut at the end of the yard and is of the loess type already described. It is worked as a stiff mud, dried on plates under sheds with canvas curtains and burned in cased kilns. The brick have a good color.

OSKALOOSA.

The Oskaloosa Paving Brick Company has a large plant about one mile east of the square on a switch from the Chicago, Rock Island & Pacific railway. The material used is largely of Des Moines age, though some drift clay is mixed with it. The section exposed in the pit is:

		FEET.
5.	Drift, largely altered loess with some gneiss pebbles and a few large boulders dissiminated in it	20
4.	Shale, blue; makes a good brick, but does not stand the frost as well as the bottom shale	10
3.	Shale, very bituminous, "black jack"	2
2.	Coal, good quality; apparently the attenuated edge of a six foot seam formerly worked on the southern slope of this same ridge	1½ to 2
1.	Shale, grey, homogeneous except for thin lines of coal and occasional pyrite balls; plant remains abundant	30

The shale is mixed with drift clay in the proportion of about four to one. A Galesburg dry pan crusher is used, a Penfield temperer and a large Penfield brick machine. The brick are dried in a Standard dry kiln. The total capacity of the kiln is 40,000, and the brick are dried in twenty-four hours. In burning three large Dewhurst and two clamp kilns are used, the brick being water-smoked two or three days and burned in about twelve. The company has a large annual output mainly of paving brick, only a few building brick being made.

The L. C. Guthrie plant is located a half mile west of Oskaloosa on the extension of Third street. The section as seen in the clay pit here is as follows:

		FEET.
6.	Soil	2
5.	Gravel, fine	2
4.	Clay, yellow, jointy	12
3.	Clay, blue, shaly	13
2.	Coal	3
1.	Fire clay	?

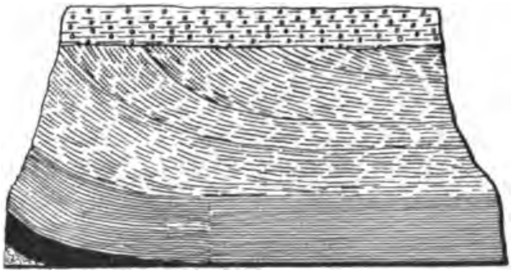


Figure 45. Clay at the Guthrie clay pit.

Of the above section Nos. 5 and 6 are Pleistocene age while all below may be referred to the Des Moines terrain. The disturbance shown in the sketch is not due to the settling resulting from the mining of the coal seam under the surrounding territory, but has taken place before the gravels of the Pleistocene were deposited as shown by the figure. The clay used is from Nos. 3 and 4 of the above section. It is moulded on a Kilk & Soris (Arian, Mich.) brick and tile machine, dried under

open sheds and burned in cased kilns. The product is of excellent quality. This factory has not been in operation since the season of 1893.

Mr. N. Logue is located just west of Guthrie. This yard has been in operation for a number of years and has an important trade. The clay corresponding to No. 1 of the Guthrie section is mixed with the black surface soil taken from a neighboring field in the proportion of 1 to 3. The bricks are hand made dried in the sun and burned in cased kilns of which four are now in use.

Northeast of Oskaloosa on Spring creek the alluvium has long been used for brick. Mr. Wes. Kirkham operates a yard. The material gathered from the immediate vicinity is worked by hand, sun dried and burned in cased kilns. Mr. Sam Kirkham has recently opened a similar yard in the immediate vicinity.

FREMONT.

John Dawson and Company have long manufactured brick and tile at Fremont. The works are located directly east of town on the Iowa Central railway. The clay used is glacial, being an altered loess similar to that used throughout the region. It is mixed with one to one and one-half per cent of coke and cinders obtained by grinding the furnace ash. This causes the clay to dry more easily and lessens the loss from checking of the ware. Coal slack has also been used, but proved not to be so satisfactory as the cinders. Experiments have also been made with saw dust. One Bennett brick and tile machine is used, and there are closed drying sheds in which the ware dries in from one to two weeks. The burning is done in Dawson kilns. The fire brick needed are made on the place from fire clay obtained at Kirkville. That occuring north of town on the Skunk river has also been experimented with, but the results so far have only been moderately successful.

EDDYVILLE.

A considerable number of the older buildings in Eddyville were made of brick manufactured in the vicinity. Of recent years the brick yards have not been very extensively operated.

James Heki is opening a new yard a short distance north of town where hand-made brick will be made from the alluvial material covering a small bottom land. A cased kiln will be used in burning the product.

Mr. Frank Harbor is also opening a yard not far from Consolidation Mine No. 8, some distance north of Eddyville. Alluvial materials will be made up by hand.

BEACON.

About one and a half miles south of Beacon Mr. William Crossin burns a few brick. Alluvial material from the bottom land of the Muchakinock is used, being moulded by hand and burned in cased kilns.

POTTERIES.

The only pottery in the county is that of Klinkoff Brothers, about three miles north of Eddyville. The clay used outcrops near the old Excelsior No. 5 mine, and is hauled from there to the pottery. Other clays have been tried, that from the Pekay mine being found to be quite good. Clay from a mile and a half north of Frederick is too sandy to be used alone, but mixed with one-fourth of fire clay makes a good ware.

The Excelsior clay alone is now used. It is soaked one hour and then ground in a pit and moulded on wheels. Three wheels are now in use and another is to be put in operation soon. The ware is dried over a furnace in about two hours. It can be dried in the sun. It is burned in a 10 by 11½ foot up draft kiln in about thirty-six hours, mainly with coal. Wood is used to finish the firing. The output consists of jugs, jars, churns, milkpans, flower pots and similar wares varying in size up to fifteen gallons. Black ware only is made, though a good grade of white ware will soon be put on the market. The operation of the pottery was suspended for a time, but work has recently been resumed. In former years about 90,000 gallons were sold annually, the output going mainly to Oskaloosa and neighboring towns.

LIME.

In the earlier days lime was burned at a number of points throughout Mahaska county. Recently the competition of the

Port Byron and the Louisiana limes has nearly forced the local product out of the market.

The limestone found within the county is not of the best quality for lime. A good rock for lime-burning must be free from impurities. A perfectly pure limestone ($Ca\ CO_3$) is rarely or never found, the rock containing some if not all of the following impurities: silica, alluminum, oxide of iron, oxide of magnesia, and traces of the alkalies. The presence of these influence largely the reactions which occur during the process of manufacture and use. It has been found that the presence of magnesia under certain circumstances is beneficial, yielding a lime of greater strength and which stands the weather better. It is very largely this which gives the limes from eastern Iowa their pre-eminence. Limes made from rock containing less than ten per cent of the ingredients mentioned above are called common, fat or rich limes. They have a specific gravity of about 2.3, are amorphous, somewhat spongy, highly caustic, quite infusible and possess a great avidity for water. In the process of slacking their volume is augmented from two to three and a half times the original mass. In hardening into carbonate of lime they shrink so much that they cannot be used as mortar without being mixed with sand. They have no hydraulic properties and are unsuitable for use under water or in damp situations, though widely applicable elsewhere.

It is lime of this character which may be burned from the limestone occurring in this county. The process of manufacture as followed here is quite simple. A rough kiln is built in the side of the hill and walled with rock or brick. Into it are loaded alternate layers of limerock and coal and the whole is fired. The capacity of the various kilns varies as does also the length of time for burning. The rock used is a very pure white limerock but only occurs in thin ledges. The Saint Louis limerock of the region is characteristically irregular in character and the rock of a quality suitable for burning lime is only a small portion of the total amount present. The fact that the different ledges vary greatly, some requiring more time than others for burning, has not been sufficiently noted by persons engaged in the manufacture of lime. All the rock at a given

place is burned together and this probably to some extent accounts for the fact that while the product is a clear, white lime, well adapted to finishing work, it is not so strong as the imported limes.

At present only two kilns are in operation. One is northeast of Oskaloosa on Spring creek and is operated by C. P. Seip. The second is about four miles northwest of Oskaloosa near the South Skunk river and is operated by Peter Nelson. Both are small common kilns and only a small amount of lime is burned. Mr. John Malone formerly operated a draw kiln near the mouth of Spring creek where a good lime was made, about 100 bushels per day being burned. This has not been in operation for four years. Other kilns were located near here, as well as just north of town near the Quaker church, near Fremont and near Bellefontaine. At the latter point considerable quantities were formerly burned and shipped down the river by boat. These kilns have not been operated for some years.

BUILDING STONES.

The quarry industry of the county is not great, being confined to a few openings for the purpose of supplying local trade only. Of the two formations occurring in the county the Saint Louis alone furnishes rock for building. A soft sandstone belonging to the Des Moines formation and occurring near New Sharon has been used to some extent in a pulverized form in making brick, but is not suitable for use as a building stone.

The upper part of the Saint Louis in Marion county near Pella, and in Monroe county opposite Eddyville, yields considerable stone. In Mahaska county, however, the most productive ledges have been cut away by erosion and only a few feet of good rock is left. These few ledges yield all the rock now quarried. They may be well seen at Peter Meyer's quarry north of New Sharon. The stone exposed here is the usual fine grained, ash to grey limestone, breaking with a conchoidal fracture and lying in thin ledges separated by partings of clay. The ledges present, which are fairly representative of those occurring in the county, are as follows.

		INCHES.
8.	Limestone	6
7.	Limestone	5
6.	Limestone	5
5.	Limestone	14
4.	Limestone	20
3.	Limestone	8
2.	Clay	6
1.	Limestone	?

At Union Mills is a small quarry not now operated, where the stone shows an exposure of five feet. It has been worked intermittently for the last nine years and has supplied foundation rock for the mill and other buildings near. A similar quarry, also abandoned, is located opposite the McBride mill three miles southwest of Indianapolis.

Near Peoria in the northwest part of the county, stone is occasionally taken out at a number of points along Skunk river and Buckeye creek. W. P. Barnard and A. D. Smith operate small quarries for the local trade about three miles south of Peoria. North of Oskaloosa, near the city water works, is a bluff where stone is frequently quarried. The rock is of the usual character. Northeast of town, near the mouth of Spring creek, rock has been taken out for the construction of a dam and the foundation of a mill. The stone comes mainly from two ledges from sixteen to twenty inches thick. A short distance south of Given similar ledges are quarried to a small extent from the banks of the Muchakinock. About one mile south of the station is the Castle quarry, in which, beneath eight to ten feet of stripping, there is an exposure of thin shelly limestone about three feet thick. Below that are two ledges of heavy limestone from which the main outcrop of the quarry is taken.

The sandstone found at Raven Cliff has never been utilized. It is of good color, is easily quarried and of inexhaustive quantity. Though soft it is believed it is sufficiently hard for all ordinary purposes. The ease with which it could be worked and its good color would render it quite valuable.

The stone quarried in the county sells at from $1.50 to $3.00 per perch, depending upon the quality of the stone and the locality at which it is quarried.

SOILS.

The soils of Mahaska county belong to two types which, while different in origin, are not greatly different in character.

The uplands over the entire county are made up of the drift over which has been spread a thin mantle of loess. The loess has usually a thickness of ten to twenty feet. It differs somewhat from the loess found along the Missouri river and long known as the bluff formation. It is less porous and has more of a clay-like character. The upper portion, from six to eighteen inches, has become changed, being blacker and containing humus. This graduates below insensibly into the clay-like loess. The black upper portion forms the soil over the greater part of the county and the loess-derived clay is the usual subsoil. The combination is very productive, being especially well adapted to corn.

Along the river and the smaller streams are flood plains of widths depending largely on the size and age of the river, and over these the second type of soil occurs. This resembles in general appearance the upper portion of the soil just described and is distinguished from it by the fact that the subsoil is exactly similar to the soil itself. This deposit is further distinguished in its mode of origin, not being developed *in situ* from the material beneath but being washed in from outside sources.

That the river itself frequently changes its position relatively to the sides of the valley is a fact patent to the observation of all. A big ox bow becomes cut off, is then a slough, and finally silts up and becomes bottom land, the river in the meantime running on the opposite side of the valley. The river thus running first on one side and then on the other, cuts out a wide valley. In times of high water these low lands are covered by water which, having only a slow motion, is forced to drop part of its load and thus the low lands are built up. Another factor quite important is that the bluffs on either side on being exposed to the air crumble down easily and wear back often to a position considerably beyond any at which the river ever washed their base. The loess above being loose and here thin, yields readily to overplacement and creeps down the slopes of the hills. The upper or changed portion being that

which is looser, yields most readily, and thus the soil of the uplands is in reality the source of the lowland soil. In the latter position it is however, mixed more or less with the extraneous drift matter and is somewhat thicker so that its properties are slightly different. On the whole however, it requires the same cultivation and yields much the same crops.

WATER SUPPLY.

Mahaska county is quite abundantly supplied with surface water. The three larger streams of the region do not go dry even in the most protracted drouths, while their numerous tributaries usually afford an abundant supply of excellent water for agricultural and stock purposes. This together with the large amount of grass land has made the region famous for stock raising. Wells may be obtained in almost any portion of the county at moderate depths. Throughout the drift are small pockets of sand and gravel which yield an unfailing supply of good water. These are of irregular distribution and do not form horizons which can be traced over any large area. At the base of the drift, between it and the indurated rocks is a good water horizon.

The Des Moines beds do not often yield good water, it being usually impregnated with sulphur and mineral salts. For this reason the mines largely depend upon reservoirs of surface water. The Saint Louis here as elsewhere usually yields water, it being found in the sandy layers between the limestone ledges.

WATER POWER.

The larger streams of Mahaska county are capable of yielding considerable power. The total fall of the North Skunk, within the limits of the county is sixty feet; of the South Skunk seventy-five feet, and of the Des Moines fifty-four feet. The amount of water in these streams has not been calculated, but it is considerable and has always been adequate to all demands made upon it.

There are now on the North Skunk three mills which derive their power from that stream. The Union Mill (Tp. 77 N., R. XV W., sec. 22, Se. qr.) has a five foot fall and thirty-five

horse power is now used. At the Roberts mill (Tp. 77 N., R. XIV W., sec. 4. Nw. qr.) there is a seven foot fall and thirty-five to forty horse power is generated. At the McBride mill (Tp. 76 N., R. XIV W., sec. 15, Se. qr.) there is an eight foot fall and power is generated for two forty horse power wheels. These mills have been in operation for a number of years and only in a few instances has the water supply been insufficient.

On the South Skunk river two mills are now in operation, and another is being built. The Albert mill near the Oskaloosa city water works station, (Tp. 76 N., R. XVI W., sec. 25, Sw. qr.) has been in operation for twenty-seven years. There are three wheels here and from forty to sixty horse power is utilized. In the last ten years the condition of the water has only caused the mill to be idle a few days. Four miles northeast of Oskaloosa a new mill is being built which will use about sixty horse power. Courier's mill, seven miles east of Oskaloosa, is one of the older mills on the river and uses the usual horse power, forty to sixty. At this mill power is used not only for grinding but a small dynamo is also driven which lights the mill and a few neighboring houses.

There are no mills along the Des Moines, for, while there is an abundance of water and good sites are not rare, the cost of damming so large a stream has heretofore proven prohibitive. At the time it was proposed to utilize the river for slack water navigation, it was carefully surveyed and three of the proposed dams were located in the county. Number 18 was a short distance above the mouth of the Muchakinock, number 19 was almost directly west of Given and number 20 was near the Bellefountaine. All of these sites are available and considerable power could be readily obtained.

The importance of water power derived from the smaller streams is being newly appreciated. The cheapness and ease with which it is obtained, combined with its permanent and desirable character, render it a source of profit. Transformed into electricity it is readily available at considerable distances from its source.

ROAD MATERIALS.

There is in this county a large and readily available supply of good road material. The gravel beds which in some localities form so prominent a part of the drift are not here common. Such gravel as is obtained usually comes from along the rivers, and the beds found there are largely the result of the resorting action of the present streams whereby the finer materials of the drift is washed away and the gravel left in beds. The gravel terrace at Eddyville, already mentioned, seems to have been formed at some earlier period in the history of the river.

Sand is obtained at a number of points in the drift and large quantities are shipped from Eddyville to Oskaloosa for use in street paving.

Clay of such a character as to be readily available for road making in the form of burned clay can be obtained at almost any point in the county. The shale and slack from the old dumps at the mines, after burning, yield a very desirable article for road making. The use of this material before burning is, however, usually a great mistake, as it slacks and in wet weather is nearly as bad as the loose dirt. Paving brick of excellent quality can be manufactured at several points and are already largely used in Oskaloosa. The expense of manufacture renders them unavailable for use outside of cities.

Rock of good character for road purposes can readily be found along any of the larger streams. For its use it is imperative that the ground be thoroughly prepared before it be laid down and the rock be broken carefully before being laid. No stone more than one and one-half to two inches in diameter should be placed on the road. At certain points in the county where rock has been used in macadamizing, the pieces used have been so large the people prefer to drive in the mud along the roadside rather than jolt over the rough stone of the "improved" road bed. Such work might almost as well not be done at all.

STATISTICS.

The following table shows the amount and value of the various mineral products of Mahaska county for the year 1893:

Coal—		
Amount—tons	1,093,530	
Value		$1,727,777.40
Clay—		
Brick—		
Amount—		
Building	2.353,000	
Paving	4,500,000	
Value		53,857.00
Tile—		
Amount	1,125,000	
Value		11,425.00
Building stone—		
Amount—perch	900	
Value		1,800.00
Total		$1,794,859.40

ACKNOWLEDGMENTS.

In the preparation of this report the writer has received important help from many people. The officers of the various mining companies have been especially hearty in their co-operation and much of the value of the report is due to the freedom with which their information has been given. Because of their wide experience the officers of the Consolidation, Excelsior, American, Whitebreast and Columbia mines have been especially helpful. The others have without exception been equally willing, and have in many cases conveyed important information. Acknowledgments are also especially due Mr. Arthur C. Spencer from whose field notes, pages 351–365 are largely compiled.

Coal—

Amount—tons 1,093,530

GEOLOGY OF MONTGOMERY COUNTY.

BY

ELSTON HOLMES LONSDALE.

GEOLOGY OF MONTGOMERY COUNTY.

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CONTENTS.

INTRODUCTION.

Early in 1867, a reconnoissance of the region lying between Des Moines, Iowa, and Nebraska City, Nebraska, was undertaken by Dr. C. A. White, State Geologist of Iowa, and Professor F. B. Meek of the United States Geological Survey. This preliminary survey was made at the instance of Dr. F. V. Hayden for two purposes: First, to connect the geological formations of Iowa with those in Nebraska, and, second, to trace out the coal beds in their western extension*.

Coal measure strata were found to cover the whole area between the Des Moines and the Missouri, and the conclusion was reached that the workable beds of coal are confined to the lower coal measures. The approximate depth at which they might be discovered by boring at Nebraska City was specified†. The results of this geological reconnoissance in southwestern Iowa, so far as they pertain to Montgomery county, were published by Dr. White in 1868‡, but later they were elaborated and republished in 1870§.

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*Final Rept. of the U. S. Geol. Surv. of Nebraska, etc., p. 4. Washington, 1872.

†First Ann. Rept. of the U. S. Geol. Surv. of the Territories, etc., p. 7. Republished. Washington, 1873.

‡First and Second Ann. Repts. of Progress by the State Geologist, pp. 63-65. Des Moines, 1868.

§Geol. of Iowa, vol. I, pp. 362-367. 1870.

At the time of this preliminary work the country was unsettled and facilities for such work were meagre, yet notwithstanding the unfavorable conditions under which the work was prosecuted the lithological characters and the geological age of the strata were, so far as general facts are concerned, accurately determined, and the correctness of the results has never been questioned.

Later, Aughey spent considerable time in this field and arrived at somewhat similar conclusions*. His results are noted on subsequent pages.

Since the time of the observations mentioned, certain changes in the conditions of the surface have taken place which make possible more detailed investigations. The grading for railroads, the changing of water courses, the boring of deep holes, together with the partial development of some of the upper beds, afford information which was before unobtainable.

SITUATION AND AREA.

Montgomery county lies in the southwestern quarter of the state. It corners on the southwest with Fremont, itself the extreme southwestern county. Between Montgomery county and the Iowa-Missouri line on the south and the Missouri river on the west, lie respectively, Page and Mills counties. The county is rectangular in shape and has a length of eighteen, and a width of twenty-four miles.

PHYSIOGRAPHY.

TOPOGRAPHY.

The upland of Montgomery county is a gently undulating plateau intersected by the rather shallow valleys of the larger water courses and their tributaries. The surface configuration is not marked by striking features. The entire district is, with a few exceptions, under a state of cultivation and only a few small upland areas which might be designated as unarable occur. The native forestry is confined almost exclusively to

*Phys. Geog. and Geol. of Neb., p. 166. 1880.

the rough bottom along the streams. On the ridges a few patches of native prairie yet remain.

A profile run in an east and west direction shows a series of ridges and valleys lying nearly parallel and having an approximately north and south trend.

Next to the large streams there exists what is known as the first bottom, an area which is subject to overflow. Commonly it is waste land, but its areal extent is insignificent. Beyond this lowland rises the second bottom. Its general elevation above water level of the adjacent stream ranges from ten to thirty feet. It is classed with the first bottom as a terrace or flood plain. The declivity of the outer terrace is gradual, but sufficient for ample drainage. The total width of the lowland varies, ranging from a few hundred yards to perhaps two miles. It is distributed unequally and irregularly on the sides of the streams.

Commonly the slopes of the upland proper merge imperceptibly into the outer margins of the upper flood plain, and the undulations along these slopes are of more or less regularity. Higher up, the sides of the ridges grade into the nearly level prairies or plateau stretches, themselves well drained. In the northwestern townships these features are less prominent as a result of the absence of distinct drainage lines and the presence of a somewhat different superficial formation.

HYDROGRAPHY.

From what has already been said it is seen that the natural drainage system of the county is nowhere incomplete. The accompanying sketch map, figure 46, shows the courses of the principal waterways and their tributaries. Three streams traverse the entire length of the county and a fourth flows from near the northern border through the district. These are the East Nishnabotna, the West Nodaway, Walnut creek, and Middle Tarkio river. These large streams each receive numerous affluents. All the streams are tortuous. The waters flow first against the sloping bluffs on one side, then against those of the opposite, and the lengths of the courses are thus nearly doubled.

In general the valleys along the larger courses vary but little in areal extent and decrease in width but gradually toward the head waters. The larger streams are confined to channels not more than 200 or 250 feet in width, and are enclosed by banks rising ten or twenty feet above low water. They lie not

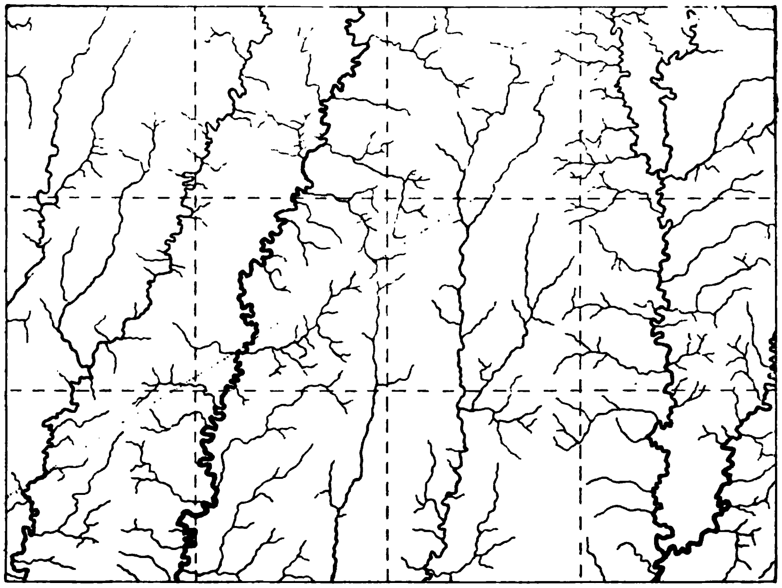


Figure 46. Sketch map of Montgomery county showing drainage.

wholly in unconsolidated beds, for constant corrasion has cut the channels as much as 100 feet below the upper stratified beds of the adjacent hills.

Concerning the age of these drainage basins there are certain features which, if considered alone would seem sufficient to fix the exact date when the work of corrasion began. Combined, the data afford conflicting evidences and render a classification difficult. In the first place the upland topography is not of the drift variety. Although present, the thickness of the drift is not great, and the preglacial cuttings were so deep that they practically determined the character of the postglacial relief. The hard limestones stand well above the water level of

the streams and bear evidence of erosive action on an extensive scale. On the other hand the main beds of drift lie in place, almost exclusively over the upland bedded rocks. Hence, if ever deposited in the rock-bound valleys the drift has been later removed or altered beyond recognition as original deposits. Those beds which were laid down during the retreat of the ice after the work of extensive erosion had ceased must be excepted. Certainly there is evidence pointing to the fact that the valleys of the East Nishnabotna and of the Nodaways have been formed either in very early Pleistocene time or in the later Neocene. At all events they are very old. The smaller streams doubtless originated as the waters from the melting glaciers began to drain off freely.

HYPSOMETRY.

Little or no attention has been directed toward the relative altitudes of the various points in Montgomery county. The minimum elevation above sea level is approximately 960 feet. It is found at the exit of the East Nishnabotna. The probable maximum height is in Lincoln township, where the altitudes range from 1,250 to 1,375 feet above the sea level, and in extreme cases 300 feet above the base of the nearest valley. It may be that further eastward, between the valleys of the East Nishnabotna and West Nodaway river, the altitudes are as great as in Lincoln township; for there is a noticable uniformity in the upland elevation. The altitudes of some of the railway points above sea level as given by Gannett, are as follows: Red Oak, 1,032; Villisca, 1,050; Coburg, 1,004; Hawthorne, 1,056. The slight amount of variation in the respective altitudes of the points mentioned is explained by the fact that they are all situated in or near the valleys.

STRATIGRAPHY.

General Geological Structure.

The unstratified rocks of Montgomery county belong to the Carboniferous and to the Cretaceous, while the unconsolidated materials above these belong to the Pleistocene. Along

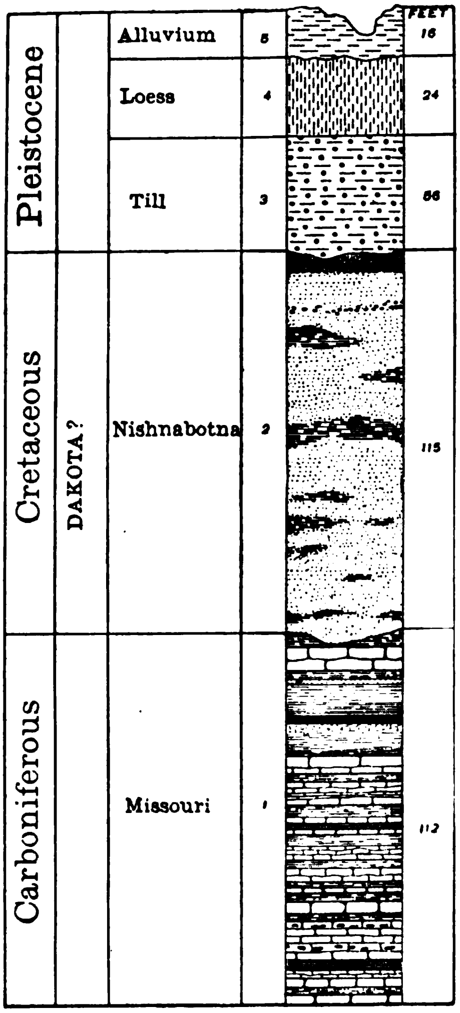
the water courses and some of their more important tributaries the bedded rocks crop out with sufficient frequency to afford some insight into the geological structure of the region. It is important, however, on account of the limited number of exposures and the distances respectively between them, to consider each outcrop somewhat carefully and critically. In addition, each boring must be studied, and conclusions must be drawn, not from individual sections, but from a compilation of all the information obtainable either in Montgomery county or in neighboring areas.

CLASSIFICATION OF FORMATIONS.

The following table indicates the divisions and the relations of the formations occurring in the county:

GROUP.	SYSTEM.	SERIES.	STAGE.	SUB-STAGE.
Cenozoic.	Pleistocene.			Alluvium. Loess. Till.
Mesozoic.	Cretaceous.	Upper.	Dakota.	Nishnabotna.
Paleozoic.	Carboniferous.	Upper.	Missouri.	

General Vertical Section.—The exposed beds of Montgomery county have an aggregate thickness approximating 200 feet. This includes a thickness of perhaps seventy feet of unconsolidated beds. The perpendicular measurements given in plate x are not secured at a single point, but represent the combined thickness of the beds occurring above the lowest elevation within the district.



GENERAL SECTION OF GEOLOGICAL FORMATIONS IN MONTGOMERY COUNTY.

General Cross-Section.—To further illustrate the relations of the several formations on the county figure 47 is inserted. With the exaggerated, vertical scale the principal features are fully brought out; the profiles and unconformities are shown. The section extends from the northeastern corner of the county, through Red Oak to the Mills-Montgomery line. The coal seam near Milford appears to dip westwardly and at the same time becomes thinner. The upper six-inch seam, described in subsequent pages, dips similarly and must pass into bituminous shale, possibly before the center of the area is reached.

Figure 47. Geological cross-section through Montgomery county along the dotted line in figure 46.

Geological Formations.

CARBONIFEROUS.

Upper Carboniferous or Coal Measures.

MISSOURI STAGE—UPPER COAL MEASURES.

The lowest rocks having surface exposures in the county belong to the Carboniferous system. They extend over the district, but are covered in part by the Cretaceous beds. Only the upper coal measures, or Missouri stage, is represented. It is the top rock of the lowlands and sometimes lies next to the drift in the hills. The measures can be traced almost the entire length of the county, both along the West Nodaway and the East Nishnabotna rivers and may be recognized along Walnut creek in the west-central and southern portions in the banks of Tarkio in the south-central, and of Middle Nodaway in the east-central, near the eastern boundary of the

county. These exposures have perpendicular faces of from one or two, to thirty feet. Generally only a few ledges are visible.

General Characters.—The formation has been roughly eroded and its upper surface is furrowed with deep channels and depressions. A profile of this surface would be badly broken. The limestones withstand the action of weathering to a greater degree than the clay shales which are so characteristic of the same geological horizon farther east. Considering only the natural exposures in Montgomery county limestones seem to predominate, although argillaceous beds do occur in considerable thickness. However, a reference to the records of the deep holes which have been drilled in this, as well as in adjoining counties, shows the respective thickness of the limestones and shales to be just the reverse of what is the case in the greater number of the exposures. To illustrate the conditions mentioned a number of sections will be here inserted.

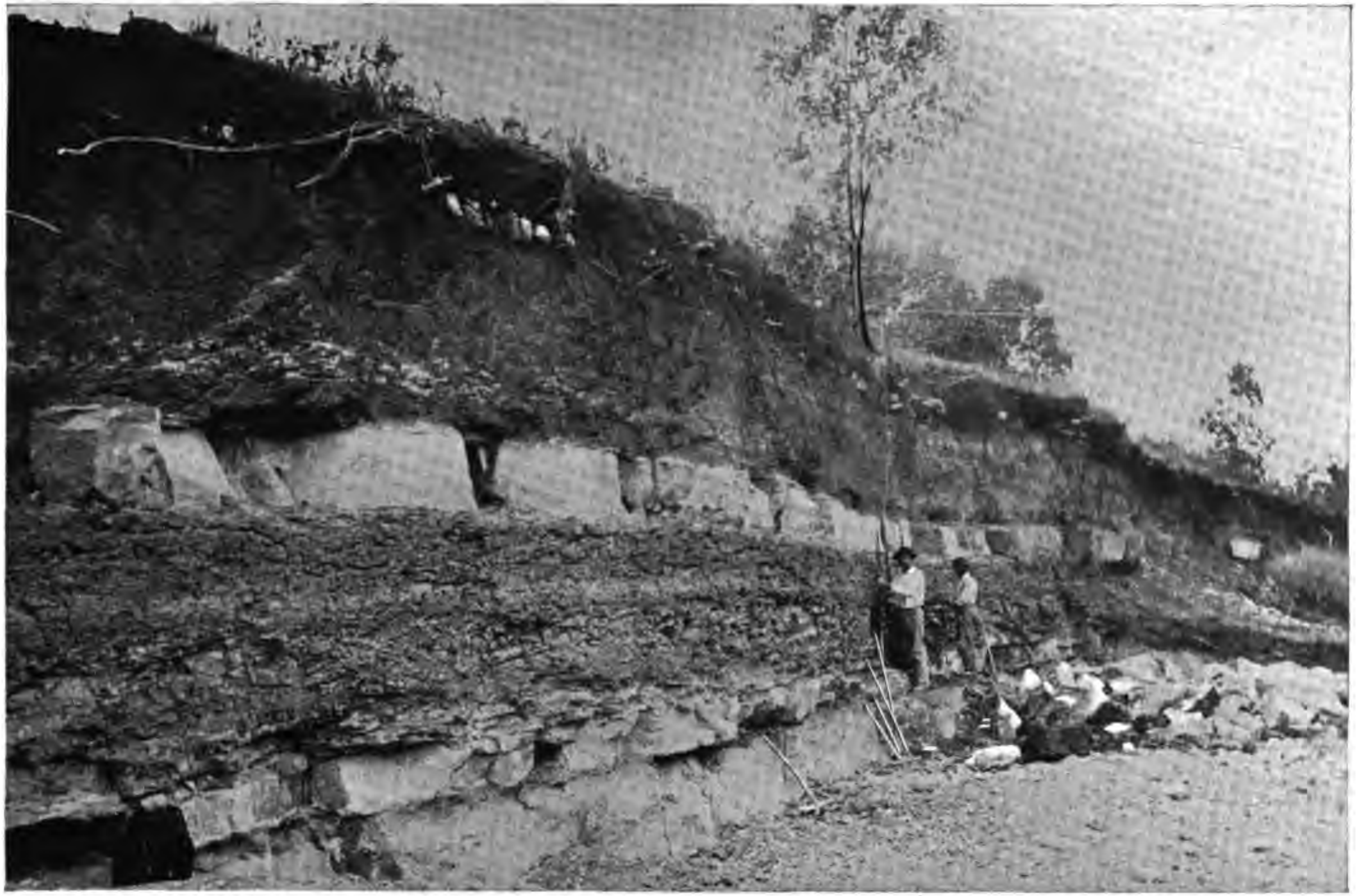
DESCRIPTION OF TYPICAL SECTIONS.

Stennett Quarry.—The following sequence is shown at the W. Stennett quarry on the Red Oak and Griswold branch railroad, just north of Stennett:

		FEET.	INCHES.
12.	Soil and loess	8	
11.	Clay, residuary, red to brown in color	1	4
10.	Limestone, weathered	2	
9.	Shale, argillaceous		7
8.	Limestone, hard	1	8
7.	Shale, clayey, buff to grey	3	7
6.	Limestone, earthy, in part ocherous	2	6
5.	Limestone, shaly	3	
4.	Limestone, impure, earthy	1	
3.	Limestone, hard, sub-crystalline		7
2.	Limestone, contains much dark chert		6
1.	Limestone, in thin layers	6	

Number 8 is perhaps the most prominent ledge on either side of the river in this vicinity. Its character is persistent and being always a single ledge it serves well as a guide in connecting sections.

Fate Quarry.—At the Fate quarry (Tp. 73 N., R. XXXVIII W., sec. 26, Se. qr., Ne. ¼) which lies across the river from Stennett, the prevalence of the hard beds is noticeable. Plate xi



TYPICAL EXPOSURE OF THE MISSOURI STAGE OF THE COAL MEASURES; FATE QUARRY, STENNETT.

shows the present quarry. The exposure at the old quarry is described as follows:

		Feet.	Inches.
16.	Limestone fragments in residuary clay	5	6
15.	Shale, calcareous		6
14.	Limestone, grayish, fine-textured	1	7
13.	Shale, argillaceous, buff to grey	3	4
12.	Limestone, earthy, flinty in upper part	1	2
11.	Limestone, texture coarse	1	
10.	Limestone, upper two feet hard, lower part earthy and bearing chert	2	8
9.	Clay, buff	1	
8.	Limestone, "blue"		8
7.	Limestone, 4-inch ledge, chert in upper part	1	7
6.	Limestone	4	
5.	Shale argillaceous, impure		2
4.	Limestone, two ledges, both with chert	2	2
3.	Limestone, dark grey, soft	1	5
2.	Limestone, "blue"	1	5
1.	Shale, argillaceous	1	6

Numbers 1 to 5 are not now exposed, but are known to occur as given, and the first of these is said to extend to the water of the river. At the mill a short distance down the stream it is seen resting on a bituminous shale. This shale is again shown in a sharp ravine about a quarter of a mile southward, and here the thickness is measured as sixteen inches. Along Pilot branch near the center of section 26, to the west of Stennett quarry, it is more than three feet thick and overlies two feet of shaly limestone which in turn rests on a hard fossiliferous limerock. The bituminous vein at this point is perhaps eight feet above the river, and in the ravine mentioned its elevation is about the same; indicating conclusively that the strata in this section have an appreciable dip to the north.

Fox Quarry.—Just a quarter of a mile north from the northeast corner of Montgomery county there is another good exposure of coal measure strata. This is at the Fox quarry on the south bank of the West Nodaway. The order of the beds is as follows:

		Feet.	Inches.
11.	Limestone, decomposed, and clay	2	
10.	Shale, argillaceous	4	
9.	Limestone, two ledges; calcite lined cavities	3	7

		FEET.	INCHES.
8.	Shale, calcareous, fossiliferous	1	
7.	Limestone, sub-crystalline	7	1
6.	Shale, calcareous		
5.	Limestone, brownish		
4.	Shale, grey in upper part, black fissile at bottom	2	6
3.	Limestone, dark grey, coarse-textured		9
2.	Shale, upper two-thirds red to grey; lower portion brown to black, laminated	2	1
1.	Limestone (partly exposed)	1	

The base of this section is probably twenty feet above the river at this point.

Smith and Fisher Quarries.—Near Milford in the extreme northeast portion of the county, the Carboniferous consists almost entirely of limestone in ledges from a few inches to more than three feet in thickness. Combining the outcrops shown at the Smith and the Fisher quarries, which are on opposite sides of the river, the following sequence is secured:

		FEET.	INCHES.
6.	Soil and loess	5	
5.	Limestone, shaly	1	
4.	Shale, impure	2	6
3.	Limestone, one ledge	3	3
2.	Limestone, shaly	1	6
1.	Limestone	1	

Milford Milldam.—At the milldam at Milford there are shown:

		FEET.	INCHES.
6.	Soil, drift and weathered limestone	9	
5.	Limestone, rather coarse	1	9
4.	Shale, calcareous		2
3.	Limestone, greyish-brown with calcite-lined cavities	1	8
2.	Shale, dark grey	1	
1.	Limestone	1	11

From these detailed sections the lithological characters of the uppermost rocks of the Missouri stage in the northeastern quarter of the county are shown to be in general quite similar to those noticeable in the central region.

Walnut Creek Section.—In the northwest quarter of Montgomery there are no Carboniferous rocks in sight; the post-glacial drainage not having cut through the drift. The most

northwestern outcrop is along Walnut creek (Tp. 72 N., R. XXXIX W., sec. 1, Ne. qr., Se. ¼). The order of the division is here given:

		FEET.	INCHES.
6.	Loess	3	
5.	Limestone, weathered into thin layers	5	
4.	Limestone, grey to buff	1	8
3.	Limestone, thin layers		7
2.	Limestone, two ledges	1	2
1.	Limestone, "blue"	1	3

Shales are here absent unless concealed by debris.

Climax Quarry.—Not far from the old village of Climax, at the extreme southwest, at the crossing of Walnut creek and the north line of section 30 of West township, a predominance of the softer strata is noticeable. The section runs as follows:

		FEET.	INCHES.
7.	Soil, boulder clay and sand	1	6
6.	Limestone, very fine-textured	1	
5.	Shale, in part calcareous	3	
4.	Shale, argillaceous	2	2
3.	Limestone, earthy	1	
2.	Shale, dark grey	1	
1.	Limestone, earthy	1	6

In the south-central portion, along the banks of the Tarkio, both north and south of the Montgomery–Page county line, the coal measures are represented by limestones rather than argillaceous materials. Such is also the case at Corning, ten miles east of Montgomery county. The limestones here have a total thickness of twelve feet. The bottom of the exposure is nearly on a level with the water in the East Nodaway river.

Summarizing the characteristics of the Upper Carboniferous beds in Montgomery county it may be said that sandstones are practically absent; shales occur in thin beds and limestones are prominent.

DESCRIPTION OF DEEP DRILL HOLES.

Since the visit of White and Meek* to this region deep drilling has been carried on at many points in search of coal or water. When expecting to find coal it has been customary to rely upon the theoretical estimates given by the authors mentioned. These attempts to locate coal seams have by no means

* U. S. Geol. Surv. of Territories, 1867, 1868, 1869. p. 7. 1873.

always resulted successfully. The churn, or slush drill has usually been employed and the records obtainable are not so satisfactory as where the core drill is used; yet it is not impossible to get an idea of the character of the strata from the churnings carefully preserved. It does not seem advisable to draw absolute conclusions from such data as to the thickness of a particular stratum, and at all times it is necessary that an allowance be made for inaccuracies liable to arise from a lack of care in the determination of the thickness and characters of each bed passed through.

From time to time holes have been put down in various sections of Montgomery county. These have varied in depth from that of the common surface well to 650 feet. The deepest borings have been prosecuted at Red Oak and Villisca.

Red Oak Drilling.—The record here given presents a somewhat condensed section of the Red Oak deep prospect hole*.

		FEET.	INCHES.
45.	Loess	30	
44.	Sand, and dark shales	40	
43.	Sandrock	3	
42.	Shale, marly above, indurated below	21	
41.	Shale, siliceous above, marly below	99	6
40.	Limestone		6
39.	Shale, dark	5	
38.	Limestone	3	
37.	Shale, argillaceous	1	6
36.	Limestone, earthy	5	
35.	Sandstone	8	6
34.	Shale, argillaceous, blue	4	
33.	Limestone, grey	3	6
32.	Shale	6	
31.	Limestone, impure	2	6
30.	Shale, gray above, black at bottom	3	10
29.	Limestone, in thin ledges	3	
28.	Shale, thin indurated layers in upper part	10	6
27.	Limestone	1	9
26.	Limestone more or less shaly	25	
25.	Limestone	3	
24.	Shale, argillaceous	12	
23.	Limestone	13	
22.	Shale, siliceous, dark	10	
21.	Limestone	3	

* Hist. Mont. Co. p. 422. 1881.

		FEET.	INCHES.
20.	Shale, grey below, upper four feet bituminous	17	6
19.	Limestone, grey	2	
18.	Shale, siliceous above, clayey below	10	
17.	Limestone, impure	2	6
16.	Shale	6	8
15.	Limestone	23	
14.	Shale, argillaceous above, calcareous and sandy below	24	
13.	Limestone, grey	6	
12.	Shale, variegated	73	
11.	Limestone	2	
10.	Shale, siliceous above	12	
9.	Limestone	7	6
8.	Shale, argillaceous	3	
7.	Limestone	1	6
6.	Shale	4	
5.	Limestone, marly partings	5	
4.	Shale, calcareous, clayey and variegated in lower part	9	
3.	Limestone, impure, grey	14	
2.	Shale	19	
1.	Limestone	3	

Numbers 42, 43 and 44 of the above section are probably Cretaceous beds and all below these numbers certainly belong to the Missouri stage.

Rosacrantz Prospect Hole.—A deep hole was put down in Tp. 73 N., R. XXXVI W., sec. 31, Nw. qr., Se. ¼, to a depth of 230 feet. Carboniferous rocks were reached ninety feet below the surface under seventy feet of Cretaceous and twenty feet of Pleistocene. This is known as the Rosacrantz drilling. The record preserved is as follows:

		FEET.	INCHES.
10.	Soil, loess and boulder clay	20	
9.	Sandrock, friable	70	
8.	Shale, argillaceous, grey	67	
7.	Limestone	1	4
6.	Shale, argillaceous		4
5.	Coal	6	
4.	Shale, argillaceous, grey to dark	1	6
3.	Shale and limestone in alternate layers usually from 3 to 12 inches thick	67	
2.	Shale, bituminous	2	
1.	Limestone (not entered)		

McCracken Deep Drilling.—In this same neighborhood, in Tp. 75 N., R. XXXVII W., sec. 36, Nw. qr., Ne. ¼, another hole was bored in search of coal. The surface of the ground at this point is perhaps fifteen feet above a small tributary of Seven Mile creek. The section furnished of the McCracken drilling is here inserted.

		FEET.
10.	Soil and loess	25
9.	Boulder clay and sand	10
8.	Clay, silicious. yellow	65
7.	Limestone	4
6.	Shale, light to dark grey	30
5.	Limestone	2
4.	Coal	½
3.	Shale, indurated in part	96
2.	Limestone	1½
1.	Coal and shale, bituminous	2½

At this place the Carboniferous rocks lie next to the drift, the Cretaceous having been completely eroded. Number 1 was given as from two and one-half to four feet thick, and made up of coal, but other evidence would go to show that a considerable part of it is nothing more than bituminous shale, and that the coal is the Nodaway vein, of which mention will be made.

Villisca Prospect Hole.—No account was kept of the materials passed through in the well put down near Villisca (Tp. 71 N., R. XXXVI W., sec. 26, Ne. qr., Sw. ¼) until the depth of 428 feet was reached. After that the following strata were met with:

		FEET.
10.	Shale, somewhat variegated	62
9.	Shale, indurated, light in color	14
8.	Shale, bituminous, fissile in part	13
7.	Coal and fissile black shale	5
6.	Fire clay and shale	16
5.	Shale, argillaceous	14
4.	Shale with thin limestone ledges	39
3.	Shale, dark, colored, hard	14
2.	Limestone	3
1.	Shale, dark	22

In this portion of the hole practically nothing but shales were encountered.

The records presented show the character of the strata met with in sinking the principal drill holes in Montgomery county. Other shallower holes have been drilled, but the results show no conditions different from those displayed in the foregoing. They all show shales alternating with limestones, the shales in all cases predominating.

Considering these records as approximately correct there is nothing which would indicate that the upper coal measures have in any instance been passed through. The stratigraphic and lithological features are just such as mark the formation elsewhere.

STRATIGRAPHIC FEATURES.

The earlier estimates of White and Meek are known to be more or less in error. In their reports on the region in question it was claimed that the upper and so-called middle coal measures of Iowa had an aggregate thickness of about 400 feet, a thickness less than the depth reached by some of the drill holes mentioned. These authors thought that the productive measures should be encounted in southwestern Iowa and points adjacent, at depths not to exceed 300 to 500 feet below the water level of the Missouri river at the southwest corner of Iowa. This level has an altitude of 907 feet above tide. The elevation of the East Nishnabotna at Red Oak is only about 100 feet above the plane. The same is true of the Nodaway at Villisca.

Supposing the Carboniferous strata in southwestern Iowa to be practically horizontal then it would not be necessary to go down more than the extreme estimate, 600 feet below the surface, at either Red Oak or Villisca before the lower coal measures would be reached. On the other hand it has been determined that the Paleozoic beds in this district are not level, but have a general dip towards the southwest. If the rate of decline be taken at the conservative and commonly accepted amount, ten feet per mile, the strata found at the surface at Red Oak, for instance, would be approximately 250 feet below water level at Nebraska City, which is about thirty-five miles distant. Assuming then this slope as actually existing, the

depth to the lower coal measures at Red Oak would not exceed 250 feet, still basing the conclusions upon the White-Meek estimates at the Missouri river.

The altitude of the top of the lower coal measures at Des Moines is about 850 feet higher than sea level. Low water mark at Red Oak is about 1,000 feet above the same datum. Hence, allowing the same dip to the strata for the lineal distance between the two points, which is ninety-five miles, a perpendicular measurement of 1,100 feet would necessarily have to be gone through before the Des Moines rocks would be reached. This thickness would consist of nearly 1,000 feet of the upper coal measures, or Missouri stage with the remainder made up of the so-called middle coal measure now regarded provisionally as a part of the Des Moines stage*.

At Glenwood, Mills county, about twenty-five miles directly west of Red Oak, the corrected elevation of the railroad track is 980 feet above sea level. Several years ago, in the northwestern part of Glenwood at an elevation of 152 feet above the track, a well 2,000 feet deep was bored in search for water. Samples of the drillings were carefully taken and preserved by S. Dean. The section will not be inserted in full, but since what is true of the formation here applies equally to the lower rocks of Montgomery county, certain noticeable points brought out in the record may be mentioned. The recent examination of the drillings suggests a number of conclusions which differ very materially from those offered by Call†.

The base of the upper coal measures was put by Call at 317 feet from the surface. There is surely no sufficient reason for such a statement. The strata for a great distance below this limit are evidently not different in general character from those of the individual rocks which lie above. Beds of argillaceous shales alternating with layers of limestone extend to a depth of more than 1,400 feet below the surface. It would be more natural and consistent to set the limit of the upper measure in this drill hole at a depth of about 1,500 feet, and concede

*Iowa Geol. Surv., vol. II, p. 120, 1894.

†Proc. Iowa, Acad. Sci., vol. I, pt. ii, pp. 60-63. Des Moines, 1892.

the lower 500 feet to the Des Moines stage. A careful examination of the drillings below the upper coal measures as thus limited results in the finding of very fine-grained white to yellow sandstone with an occasional layer of common clay shales. Such materials extend to the bottom of the hole.

In Cass county, at Atlantic, thirty miles northeast of Red Oak, a well was bored to a depth of more than 1,300 feet. Down to 1,100 feet the rocks passed through consisted almost exclusively of the shales and limestone which are characteristic of the upper coal measures. Below that depth the materials were just such as appeared in the lowest 500 feet of the Glenwood well. The elevation at the Atlantic well is just a little above that of the surface at Glenwood. If the dip of the strata toward the southwest as given above is correct, this variation in the depth at which the sandrock formation was reached at the two localities would nearly be explained, the distance between the points being thirty miles.

Near Clarinda, twenty-five miles southeast of Red Oak, at an elevation of approximately 1,020 feet above sea level a well 1,002 feet deep was put down in the effort to ascertain if thick coal veins were present. It was shown that below the drift the entire thickness was almost wholly of shales and limestones. Here also it would appear that the upper coal measures were not passed through.

Prospecting has also been carried on at Shenandoah, twenty miles nearly south of the county seat of Montgomery county. A hole was bored 700 feet deep passing through shales and limestones only. At the Iowa school for the deaf near Council Bluffs, an 800-foot drill hole disclosed mainly argillaceous shales and hard limestones.

Results from investigations at other points might be given but with the data from the Red Oak and Villisca deep holes, in Montgomery county, and from several localities on the different sides of the district the structure is pretty well shown. These records, taken to depths of from 500 to 2,000 feet, reveal the character of the underground beds and counting upon the data as in a manner accurate the following conclusions are drawn: (1.) The combined thickness of the divisions of the

upper Carboniferous in Montgomery county is in the neighborhood of 2,000 feet. (2.) The upper coal measures have a thickness in the same region of from 1,400 to 1,500 feet.

Broadhead,* in support of a similar opinion, records the upper coal measures in Atchison, the northwest county of Missouri, as more than 1,100 feet, and the upper Carboniferous as 1,900 feet in thickness. The estimate for the upper division has more recently been corroborated by Winslow.†

After briefly reviewing the Iowa-Nebraska coal field and the work of Meek and White in that territory together with that of Broadhead in Missouri, Aughey argues that the lower coal measures beds might be reached at any locality along the river from Omaha to Plattsmouth at the depth of from 800 to 900 feet below the surface.‡ The information already given would certainly tend to prove that this opinion is not well founded.

BITUMINOUS DEPOSITS.

The position of Montgomery county, as well as of the entire southwest section of Iowa, with respect to points at which the mining of heavier veins of coal is carried on, is such as to make the finding of coal within the district very desirable. Prospecting has been prosecuted in a number of localities with widely varying results. These investigations were, as a rule, made at a time when the stratigraphic features of the coal measures were not understood; at a time when the horizontal and vertical extent of coal beds was counted upon as persistent through great belts of the formation.

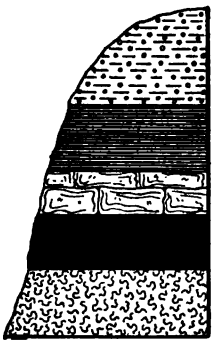
In opposition to this view, Keyes§ suggests the conditions existing in other fields as equally prevalent in the Iowa measures. That is, instead of the one or two or three coal strata persistent throughout a large area, there are numerous separate beds which are disposed in lenticular basins of varying areal extent. This idea has later been accepted by Winslow‖ and has again been treated more fully by Keyes¶. Hence because

* Iron Ores and Coal Fields, Geol. Sur. of Mo., pt. ii., pp. 6 and 98. 1873.
† Prelim. Rep. on Coal, Mo. Geol. Sur., p. 23. 1891.
‡ Phys. Geog. and Geol. of Nebraska, p. 166. 1880.
§ American Geologist, vol. X. p. 401, 1888.
‖ Ann. Rep. Geol. Sur. of Ark. for 1888. Prelim. Rept. on Coal, Mo. Geol. Surv., pp. 37-38. 189
¶ Coal Deposits, Iowa Geol. Surv., vol II, p. 155, pl. xiii. 1894.

heavy coal veins exist in certain sections, it is not to be inferred that corresponding veins will be found everywhere at the same horizon.

Lithological Character.—Past investigations have failed to reveal the presence of heavy coal seams within the limits of Montgomery county. The attempt to locate coal beds of the lower coal measures has not been successful. If such veins do occur there is no evidence whatever pointing to the presence of any such thicknesses as are found in the same geological formation in central and southeastern Iowa and Missouri. In order to best understand the stratigraphic position and thickness of the bituminous layers within Montgomery, the information afforded by the drill records in the county itself and in neighboring counties wherein coal has been reported, must be considered. But before doing this, reference will be made to the known occurrences of coal seams in the county under immediate consideration.

On the south bank of Williams branch (Tp. 73 N., R. XXXVI W., sec. 1, Se. qr., Sw. ¼) at the extreme northeast section of Montgomery county, a coal vein was discovered and mined about thirty years ago. The thickness of the layer varied from eighteen to twenty-two inches. White mentioned this occurrence but was inclined to treat it as one of little consequence and did not anticipate its becoming of any particular economic value*.



	FEET.	INCHES.
5. Drift	3	
4. Shale, dark colored	2	
3. Limestone, impure, compact	1	3
2. Coal	1	8
1. Fire clay	2	

Figure 48. Coal bed at old Westrope mine.

*Iowa Geol. Surv., First and Sec. Ann. Reports, p. 63. 1868.

The latter development, however, was quite considerable in extent. Not only has the vein been mined at this point but at numerous others of which mention will be made hereafter. The appearance of this coal along the Nodaway river has given to the vein the name of Nodaway.

At the special locality referred to in the corner of Montgomery there are no good exposures of the vein or of the associated strata. The section shown in figure 4 represents the beds as they appeared at the time mining was in progress.

At Briscoe, three miles eastward, in Adams county, the Nodaway vein is mined from three or four shafts. The rocks at the localities in this immediate vicinity are similar to those formerly exposed on William's branch. The sequence as occurring at one of these shafts, the Plowman, is represented in figure 5. The uppermost twenty-five feet of material is drift.

	FEET.	INCHES.
7. Shale, gray, clayey	2	
6. Limestone, gray	1	
5. Coal	1	4
4. Shale, finely laminated, bituminous		3
3. Fire Clay	1	6
2. Limestone, thin bedded		8
1. Shale, sandy in part	1	

Figure 49. Coal bed in Plowman shaft; Briscoe.

There are still other localities in Adams, Page, and Taylor counties where mining of this very persistent vein has been carried on for a period of several years. At Eureka and Carbon, between Villisca and Hawleyville, near New Market, near Shambaugh, and near Clarinda, coal mining is to-day an industry of considerable importance. From two to eight slopes or shafts are now operated in each locality.

Further southward this Nodaway coal was found outcrop-cropping two miles north of the Iowa-Missouri line and Broadhead traces it to a point about fifteen miles into Missouri*.

*Iron Ores and Coal Fiel ls, Mo. Geol. Sur., pp. 394-398. 1872.

The altitudes at the different places nearly correspond with that of the Nodaway river at the point least remote from the known occurrence.

From Briscoe to Quitman the lineal distance is approximately sixty miles. East of the line connecting these two points, except as already mentioned, there is no probability of the coal vein extending for any great distance. Limestones soon predominate and but rarely are the accompaning shales of much consequence. West of the line mentioned the presence of the vein is claimed at numerous points. In Tp. 72 N., R. XXXVI W., sec. 33, Ne. qr., Se. $\frac{1}{4}$, coal was reported in a bored well at eighty feet from the surface. However, much credence is not put in this report since development, once begun, was given up before such a seam was reached.

In Page county (Tp. 70 N., R. XXXVIII W., sec. 24) at a point four miles south of Montgomery, a seam of coal supposed to be the Nodaway has been found, though with slightly less thickness than elsewhere. The only entirely certain occurrence of coal within Montgomery is the one mentioned in the northeast corner of the county. In all likelihood, however, this vein underlies at a greater or less depth a large portion of the district. In fact the eastern half, excepting possibly the region immediately adjacent to Villisca where erosion has been greater, likely bears the Nodaway vein within no great distance from the surface. It may be that in some instances the actual thickness of the coal is considerably less than the maximum found near Milford. It would seem that undulations exist in this region with the direction of the axis almost parallel to the direction of the generally supposed dip of the rocks. The trough of one of these undulations would cross somewhere in the western portion of Montgomery county.

It might be well to insert additional data relative to the Nodaway coal which has been under consideration. From what has been definitely shown it will be seen that this seam extends under a greater territory than does any other yet found within Iowa, and the possibilities of finding it under a still larger area, especially westward and southward, seems favorable.

In the western part of Fremont county the cropping out of a ten-inch vein of coal at an elevation of perhaps sixty feet above the Missouri bottoms is recorded by White*. He considered this to be an extension of the Nodaway coal, but in order to establish this fact additional field work is required. However, in case such proves to be a fact it may yet be practicable to connect the strata with the coal vein, which Meek describes as existing in Nemaha, Ote and Cass counties in Nebraska. Otherwise the Fremont exposure and those in Nebraska are probably of the same horizon, both wholly different from the Nodaway vein. About twenty miles in a northeasterly direction from the northeast corner of Montgomery county, at a depth of 262 feet, a coal seam with a thickness of from twenty to thirty-five inches has recently been discovered†. In lithological character the strata overlying the coal at this point do not wholly conform to the features of the beds over the Nodaway seam.

Through a comparison of the relative thickness of the coal as shown in these several localities a more or less persistent and regular attenuation southwestward is noticeable.

The limited amount of attention given to the occurrences in southwestern Iowa does not allow the drawing of exact conclusions as to geographical extent and the continuity of the individual layers nor to their relative position. Careful field study over a large region is necessary. The estimates and theories are not offered as final settlement of the questions. There are weighty points in their favor and it is believed the suggestions may be relied upon.

As yet but the single vein of coal has been encountered above the water level in Montgomery county. Occasional outcroppings of black fissile shale, locally known as "coal blossom," give rise to the reports of additional seams.

In almost every record of deep drill holes in southwestern Iowa and adjacent fields coal is indicated. The distance of the strata from the surface of the ground ranges from a few feet to

*Am. Jour. Sci., (2), XLIV, p. 29. 1867.
†Iowa Geol. Surv., vol. II, p. 442. 1894.

900 or 1,000; the thickness of the vein is given from a mere trace to five feet.

There stand out in this connection, two probable sources of error: (1.) Determination of the nature of the materials; (2.) Determination of the thickness of the individual beds. Errors from either of these sources are of common occurrence and usually arise from lack of care or non-appreciation of the importance of accurate work. The errors most probable which pertain to the lithological character are made up through the inability of persons in charge to distinguish limestone from sandstone or bituminous shale from coal. These mistakes have so often occurred that it is safe to believe that in certain instances where coal has been reported in the record, there was in reality nothing more than bituminous shale. A study of the surface rocks and of the reliable drill records confirms this belief. The tendency is naturally towards recognizing shale as coal. Hence, in the consideration of the reported existence of coal at the various localities, too much reliance must not be placed on the accuracy of records.

In the 560-foot prospect hole at Red Oak (see page 396) no coal was reported. Another hole, the Bolt and Crockett, was bored in section 32, south of Red Oak, and an eight-inch vein of coal was said to have been struck at a depth of about 100 feet. The elevation at the top of the hole is perhaps ten feet above the river at this point. Only a partial record of another drill hole at Red Oak, at a point probably thirty feet above the elevation of the Nishnabotna was obtainable. More than one coal vein was said to have been passed through at depths between 200 and 300 feet. The greatest thickness of any of these was given as sixteen inches.

Upon comparison of the records a great diversity in the character of the strata at the three localities is evident. In the first case the hole was deepest but no coal was struck; in the last, only a few hundred feet distant, several veins were encountered. It is not improbable that shaly layers in the latter were mistaken for coal.

*History Montg. County, p. 420. 1881.

About two miles northeast of Red Oak is the Stockslager well, 125 feet deep. A few inches of coal are reported as occurring just under several feet of black shale at a depth of about ninety feet.

In Douglas, the northeastern township, in the sinking of the Rosacrantz prospect hole (see page 397) a six-inch vein of good coal was reported at a depth of 160 feet from the surface; none lower down. Westward, a little over a mile into Pilot Grove township, the McCracken boring recorded this same six-inch vein of coal at nearly 140 feet and another seam, doubtless the Nodaway, at a depth of 230 feet. The thickness of the latter was given positively as thirty inches. The McCracken drilling was started at an elevation somewhat less than that at the Rosacrantz and this explains the difference in the depth to the upper vein at the two localities as well as the appearance of the heavier vein in the one and not in the other. Other deep holes should discover this thicker vein.

The Lenz drilling was done in Tp. 73 N., R. XXXVI W., sec. 5, Ne. qr., Nw ¼. At 114 feet below the surface or eighty feet below the water of Rose creek, a seam of coal eight to twelve inches thick was met with. This is doubtless an attenuated portion of the Nodaway coal. Again near the southern boundary of Montgomery county (Tp. 71 N., R. XXXVII W., sec. 33, Sw. qr., Ne. ¼), in prospecting for coal, J. W. Donaldson of Stanton, claims to have struck a thin vein, probably the Nodaway. This same vein is exposed at the abandoned Linquist mine about five miles southwest, in Page county.

Other reported occurrences of this seam or of other seams of coal in Montgomery county might here be recognized but more the accurate results of the drillings have been recorded already and these are deemed sufficient to indicate that while the presence of coal is evident the particular occurrences can not be satisfactorily correlated.

CALCAREOUS BEDS.

The structure of the calcareous layers of the upper Carboniferous of Montgomery county has been already referred to in an incidental but general way in the discussion of the common

character of the measures as a whole. A more specific reference is scarcely necessary.

As has been shown, limestones made up the greater proportion of the upper or exposed rock, but the deep drilling has revealed that the shales predominate lower. In the general limestone formation the material separating the individual ledges usually has a thickness of but an inch or so, rarely so much as a foot. The thinner partings are themselves decidedly calcareous and are designated, where noted in the sections as marls. They may or may not bear fossils. Some of the partings have many species of shells in great abundance. In no case are these argillo-calcareous layers of economic value.

The limestones may be arranged in three divisions, classed lithologically. (1.) Finely to coarsely textured, compact, and brittle; fossiliferous or non-fossiliferous. (2.) Finely textured, resembling number one but bearing chert. (3.) Earthy. The first and second classes make up nearly the entire calcareous division. They occur in weathered ledges frome one or two, to as many as forty inches in thickness. As a rule they bear fossils, but the extent to which they are fossiliferous varies greatly. In some of the ledges, such as are seen at the Stennett quarries and eastward, the characteristic species are so abundant and persistent as to enable the same strata to be traced for great distances merely through the recognition of the prevailing fossil forms.

The various ledges of limestone may be used for different purposes. The weathered, the thin, and the softer beds are adapted for road material, ballast or rubble. Others answer for rough masonry or for interior walls. The more solid, evenly textured rock is used for outside walls, sills, steps and for ornamental work. Some ledges that seem hard and compact when taken from the quarry are affected to such an extent by changing conditions or temperature and moisture as to make them almost valueless for outer constructional purposes. The greater number of the solid heavy beds of limestone are strong, durable, are easily dressed and admit of a superior finish. The heavier ledges which show no tendency to fracture, are used

extensively as piers, abutments and foundations for bridge work and for milldams in the larger streams.

Chemical analyses of the limestones have not as yet been made, and the exact percentage of the carbonate contained is not known. The composition of the rocks is certainly such as to warrant their use in the manufacture of lime. Years ago a white lime was burned at a number of localities within Montgomery county. In quality the product is said to have been good.

ARGILLACEOUS MATERIAL.

The clays of the upper Carboniferous are elsewhere in the state of great value and are utilized in the manufacture of various kinds of wares including pottery, sewer-pipe, drain tile, fire brick and different grades of structural brick. They belong, for the most part, to the lower coal measures, a formation characterized by great abundance of argillaceous material. The upper division covering southwestern Iowa, also contains clay shales of similar quality. They occur in beds from a few feet to nearly one hundred feet thick, and are found generally distributed throughout the formation.

It happens that all of the known heavier beds which occur within the limits of Montgomery lie almost invariably at a considerable distance below the surface. Just over the limestone ledge which rests on the coal of the northeastern quarter of the county there occurs a bed of light grey or "blue" shale which is decidedly argillaceous and plastic. Its extreme thickness is about one hundred feet. This amount was shown at Briscoe, in Adams county, three or four miles east of the northeast corner of Montgomery. Here ninety-two feet of this "shell soapstone" was passed through in putting down the new Miller shaft, and it is not improbable that prior to the glacial erosion, this thickness was considerably in excess of what is now presented. The drift detritus now rests directly upon the shale. Unfortunately no railroad line passes across this immediate region. Transportation facilities are consequently meager; otherwise the eighteen-inch coal vein, once developed near Milford, would be again opened, and the overlying shale would be put to a number of economic uses. At present, none

of the heavier clays, those employed for making pavers and other strong articles, are utilized at any point in southwestern Iowa, northwestern Missouri or eastern Nebraska. The field for trade is great, while there is a strong demand, competition in the sale of the greater number of clay products is not close. Recent excavations along the river at Villisca has shown the existence there of several shale beds, some of which are quite suitable for the manufacture of the ordinary products. One or two of the beds at this point abound in calcite fossils which render the deposits valueless. In addition to the beds mentioned it may be important to notice the few bands and layers of argillaceous materials found separating limestone ledges. Near Stennett these thinner clay strata are very common in occurrence. The thickness of the individual beds range from a few inches to several feet, but in no place is the quantity sufficient to make the deposit of any particular use.

The presence of iron pyrites in crystal form, disseminated throughout the body of the shale bed, is not so common in the upper division as nearer the base of the coal measures. Pyrites, however, appear in small quantities, and there are also hard concretions of calcareous substances, but neither of these impurities occur to such an extent as to make the use of the clays in manufacturing unadvisable or to make the product poor, or unprofitable. The sinking of the shafts to such depths as would be necessary to reach workable coal measure shales, would not be advisable nor should the mining of the ordinary deep clays be undertaken unless in connection with the working of a coal seam.

ARENACEOUS DEPOSITS.

The arenaceous beds of the coal measures in Montgomery county are of little consequence, since true sandstone appears above surface at no point and sustains no well defined position in the borings. Where reported the sandstone was soft, sometimes micaceous and more or less clayey. The appearance of the hard siliceous beds of the Missouri stage was marked but once in the records of any of the deep drill holes put down at Red Oak, Villisca or any of the country localities.

CRETACEOUS.

In reviewing the structure of the county White* set down as Cretaceous certain sandstones found along the East Nishnabotna, and placed the southern boundary of these beds at the county seat, Red Oak. Only sandstones, or friable grits, were at that time referred to the Cretaceous, and other beds found exposed were left unclassified. It is now possible, however, to extend the formation so as to cover a large portion of the district, southward as well as eastward, into Page and Adams counties respectively. The existence of these sandstones in Montgomery county west of the East Nishnabotna can not be affirmed with certainty, as no exposures of the measures appear within these limits. Just over the line in the northeastern corner of Mills county there are outcrops, and within Montgomery the records of drillings indicate the existence of the Cretaceous over the coal measures in the uplands both west and east of the Nishnabotna. In brief, the Cretaceous may be said to lie immediately beneath the glacial covering over almost the entire highlands of the area. It would in only a few instances extend to and make up the bed rock of some of the larger streams, as these have almost invariably cut through the soft sandstone down into the harder upper Carboniferous strata.

NISHNABOTNA SANDSTONE.

(DAKOTA?)

Extent.—To certain arenaceous deposits in southwestern Iowa White gave the name Nishnabotna sandstone. This sandstone is best developed along or near the East Nishnabotna river. These arenaceous beds were the only deposits of the region that were recognized as Cretaceous.

Cretaceous outliers have also been found in other counties to the north and northeast. These are doubtless of the same age as those in Montgomery county and were probably at one time connected not only with one another, but also with the beds along the Nishnabotna river. The Mills and Pottawattamie outliers are therefore but areas isolated from the general deposit through erosion.

* Geol. of Iowa, Vol. I, p. 363. 1870.

In addition to the friable sandstones in Montgomery county there are beds of an entirely different character which are now classed as Cretaceous. There appears at the top of the formation a pudding-stone conglomerate which is prominent, but less persistent than the nearly homogeneous sandrock. The micaceous and the clean clay shales, so well exposed at Red Oak, are evidently Cretaceous in age.

White took the deposit of brown massive sandstone southeast of Lewis, Cass county, as the rock presenting the typical features of the Nishnabotna sandstone. While no doubt a part of the formation, in lithological character, it is very unlike the formation at other points, being darker in color and more thoroughly indurated. False-bedding prominent in the beds elsewhere is not a feature of the Lewis rock.

Age.—The conclusion that these sandstones are of Cretaceous age is supported by Meek's discovery of leaves and imprints in the rock at Red Oak*, and by the finding of similar impressions in the development of the quarries at Lewis.

A comparison of the lithology of the Lewis stone with that of the formation at Ellsworth county, Kansas, reveals the facts that the rocks in the two states are very nearly related if not of the same horizon. The Kansas locality furnishes numerous fossil leaves and many are of the same species as those present in the beds of southwestern Iowa. The Kansas rocks have been provisionally referred to the Dakota formation.

In Iowa the formation hitherto recognized as Dakota is exposed mainly in the vicinity of Sioux City. It consists of hard impure sandstone interbedded with irregular and usually heavy bands of argillaceous shales. Some of the sandstone layers are divided into shapeless ferruginous masses and these commonly contain plant remains. Lower in the measures more friable and shaly layers also contain poorly preserved specimens of leaves.

The shales at Red Oak, to which reference will subsequently be made, may be taken as the only known extensive deposit of Cretaceous clays within this section of Iowa. Calvin† has explained

*Am. Jour. Sci., (2), vol. XLIV, p. 119. 1867.
†Iowa Geol. Surv., I, First Ann. Rep., pp. 147-148. 1893.

how the several divisions of the Cretaceous in Woodbury and Plymouth counties became deposited in a manner contemporaneously, and carrying out this theory Keyes in reviewing the geological formations of Iowa, says: "If the Nishnabotna is Cretaceous it may be the equivalent either of the Woodbury shales (Benton and Dakota) or of the Niobrara chalk." Lithologically the Nishnabotna is entirely unlike the Niobrara nor does it resemble the nearest known Benton. Its affinities, lithologically, are with the Dakota. Like the Dakota it is a marginal deposit and may have been laid down along the shore while either the Benton or the Niobrara were accumulating in the deeper parts of the Cretaceous sea.

The Cretaceous outliers are neither more persistent nor more extensive along the East Nishnabotna than along the several forks of the Raccoon. Since, however, the name Nishnabotna sandstone has already been applied, it does not seem advisable to change it until the correlation above suggested is verified, or until definite specific relations can be fixed.

The general character of the Cretaceous formation is displayed in figure 53, which was taken at the bluff just east of Coburg, at the south line of the county. The general cross-bedded character is presented and over the softer fine grained and pebbly sandstones the hard ferruginous pudding-stone stands out in some relief.

DESCRIPTION OF TYPICAL SECTIONS.

Sherman Township.—About half way between Elliott and Stennett, perhaps one hundred yards east of the Red Oak-Griswold branch of the Chicago, Burlington & Quincy railroad, lies one of the most northern exposures of Cretaceous in Montgomery county. This is the abandoned Crandall quarry. In taking out the limestone it was necessary to remove a small amount of stripping, and in doing so several feet of weathered sandstone, doubtless Cretaceous, were exposed. This exposure was perhaps thirty feet above the river to the east. The principal outcrop, however, in this neighborhood is in the central portion of section 26 about one and one-half miles south of the Crandall quarry. The following section is shown.

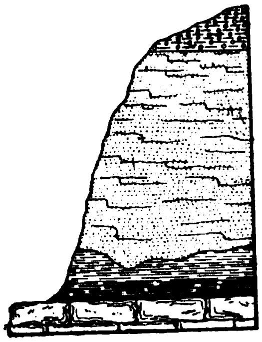


Figure 50. Upper Carboniferous and Cretaceous at Stennett.

		FEET.	INCHES.
5.	Drift	5	
4.	Sandstone	20	
3.	Shale, bituminous. coaly below	3	4
2.	Limestone, impure, earthy	2	
1.	Limestone, hard		8

Number 4, of this section is of Cretaceous age. It is a soft, slightly coherent sandstone, orange to white in color. Numbers 1, 2 and 3 belong to the upper coal measures. Number 1 is partly exposed, extending beneath the surface of the water. Not more than fifty feet or so up Pilot branch the Cretaceous sandstone is thirty feet thick extending even below the level of the water. The Carboniferous beds do not here appear, indicating the deposition of the sandrock at this point in an eroded channel or in a depression in the coal measures. The sandstone is found outcropping along Pilot branch, perhaps a third of a mile. Beyond that point it is concealed by debris.

Near the top of the ridge, about one mile southeastward from the branch outcrop is located the Miller well, 223 feet deep. After passing through 117 feet of loess and boulder clay, Cretaceous sandstone was penetrated and found to extend to the bottom of the drilling. Between the point where the well is situated and the southern boundary of the township, beds of Cretaceous from five to forty feet thick appear. They consist of sands partly indurated, and in these are found lenticular pockets of very pure light grey or drab clays. They are especially noticeable a few feet above the stream near by. The pockets vary from two to ten inches in perpendicular diameter and are commonly less than eighteen inches in horizontal extent. Contact between the sandstone and the underlying coal measures is shown only at the point just mentioned.

Near the southwest corner of section 13 of Sherman township, at the Powell spring, there is a bed of soft, light-colored sandstone exposed for a thickness of fifteen feet. The top of the sandstone is doubtless a considerable distance above but is concealed by drift debris.

Red Oak Township.—Sandstone such as noted in the southern potrion of Sherman township can be traced southward into section 2, Ne. qr., E. ½. At this point the height of the bluff is perhaps forty feet. White describes* a bed of clay at the base of the sandstone which likewise is probably Cretaceous, but at present this material is not uncovered.

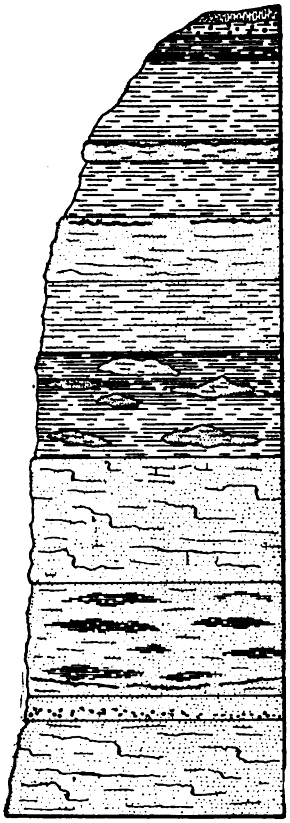
At Red Oak and in its immediate vicinity the development of Cretaceous beds is quite extensive and the variety exhibited here is greater than at any other point. Towards the summit of the hills within the town the deposits, as shown in street grades, consist almost exclusively of bright yellow clays, very arenaceous. In the cut along the Chicago, Burlington & Quincy railroad in the southeastern portion of the town there are ten feet of rather fine light greyish to chrome yellow in color, partially indurated sandstone. Just above this on the slope, for a height of nearly one hundred feet, the same soft sandrock was found; but at this point it contains numerous clay shale pockets of varying dimensions. These have been excavated and the clay utilized in the manufacture of pottery. On the lower side of the railroad, beds of argillaceous shale with a total thickness of from three to eight feet are displayed. Sandstone is interstratified in the upper portion, while under the clay there is a more thoroughly indurated sand deposit.

Further eastward along the railroad in the southwest corner of section 27 there are incoherent Cretaceous sands associated with which are one or two layers of pebbles. The figure here given represents the several kinds of materials found here and at the clay bank of the Cook brick works situated just beyond the track to tho north.

Sandstone predominates in the section given, and at "sand spring" in the northern edge of section 33 an eighteen foot deposit of light colored cross-bedded sandstone is shown.

*First and Second Ann. Rep. of State Geologist, p. 64. 1868.

Along the roadside to the west large blocks of the dark stone often covering the Cretaceous in this county, occur well towards the top of the hill.



		FEET.
13.	Loess	1
12.	Drift	1
11.	Shale, brown, impure	2
10.	Shale, grey to yellow	5
9.	Sandstone, yellow; with limonite layers	1½
8.	Shale, light grey, clean	3½
7.	Sandstone, with limonite layers	3½
6.	Sandstone, in part shaly	4
5.	Sandstone, dark brown	8
4.	Sandstone, soft below, streaks of limonite disseminated	9
3.	Sandstone, variegated, concretions of sandy limonite and pockets of clay shale	12
2.	Sandstone, with pebbles in lower part	1½
1.	Sandstone, varying in color and texture	6

Figure 51. Vertical section through the Cretaceous at Red Oak.

Another outcrop is seen at the mill (sec. 32, Sw. qr., Ne. ¼) where the Cretaceous extends to low water mark and rests unconformably on hard coal measure strata. The Cretaceous beds, beginning with the lowest, are as follows: (1.) Eight feet of very micaceous, sandy, vari-colored shale; (2.) Micaceous, sandy shale with hard sandstone bands, thickness five feet; (3.) Six feet of impure, shaly, micaceous material more or less argillaceous; (4.) Seventeen feet of shaly clay, vari-colored, rather pure.

Higher the measures are concealed by a few feet of drift above which is loess partly exposed for some distance up the slope.

Grant Township.—About half a mile east of the Red Oak and the Nebraska City branch of the Chicago, Burlington & Quincy railroad (Tp. 71 N., R. XXXVIII W., sec. 17, Nw. qr., E.½) Cretaceous rocks are indicated by the contrast in topography. From this locality southward to the extreme southern boundary of Grant township the low land of the flood plain of the East Nishnabotna ends absolutely, and rather steep slopes, made up of Cretaceous beds, stand out prominently. The shallow ravines, elsewhere unimportant and few in number, are here sharper in cross-section and occur at frequent intervals. At the most northern point of this series of exposures the vertical extent displayed is about sixty feet. There is a deposit of fine buff to

Figure 52. Cretaceous sandstone capped by pudding-stone.

white and yellow sandstone, quite friable, thirty feet thick. Over this are twenty feet of a rather coarse and darker stone of similar character, but interbedded with it are thin bands of sand cemented by siliceous limonite. The upper division of the exposure consists of alternating layers of coarse sand and siliceous pebbles imbedded in a limonite or a siliceous clay

matrix. The upper half is almost exclusively pebbles. The limit of the beds here is not disclosed, but the hill, at the foot of which the exposure stands out, rises perhaps sixty feet higher than the top of the outcrop itself, and it seems quite probable that the total thickness of the Cretaceous is almost one hundred feet. Deposits similar to the one just described are recognized southward for a distance of about three miles. The elevation of the outcrops ranges from thirty to fifty feet above the valley. The hard pudding-stone which constitutes the topmost division, is disclosed, but the softer sandstone below is covered with washed materials.

Figure 53. Typical exposure of the Cretaceous; Coburg, Montgomery county.

At Coburg, about 300 yards east of the track the combined section is as follows:

		FEET.
5.	Loess	12
4.	Conglomerate or pudding-stone with hard limonite and clays as matrix; thickness variable	9
3.	Gravel and sand in alternate cross-bedded layers	3
2.	Gravel and sand—very coarse	2
1.	Sand and gravel; light colored; variably cross-bedded	18

The bluff here is pictured in the accompanying figure 53, the pudding-stone standing out in some relief in the upper portion.

Carboniferous limestone has been quarried about a quarter of a mile south of Coburg at an elevation of perhaps ten feet above the base of the section shown. About half way between this exposure and the location of that in section 17, a bed of very plastic red and grey shale clay, with a total exposed thickness of eight feet was developed, at the railroad grade. This bed corresponds with one along the track further north (sec. 32, Sw. qr., Se. ¼) where there are nearly ten feet of red to brown more or less impure clays. The base of these clays is certainly not more than ten feet above the coal measure limestone which is exposed near the river at this point.

These Cretaceous clays constitute the impervious layer which determines the line of springs at the base of the sandstone. It seems, therefore, probable that while being decidedly variable, ranging in character from hard silico-micaceous shale to homogeneous, comparatively pure clay, that these shales are more widely distributed than has been supposed, and constitute the base of the Cretaceous throughout a large area of Montgomery county. Being heavily covered with drift their presence is rarely disclosed.

Exposures in this township remote from the East Nishnabotna are encountered at a number of points. In the northeastern quarter of section 20, along a fork of Ramp creek and a small branch entering this stream from the east, the outcrops consist of incoherent sands and fine gravels forming an extreme thickness of twelve feet. Along the south boundary line of the county, in the southeastern quarter of section 33, there appears a bed of massive light colored sandstone, twenty feet thick, which forms the bank of another fork of Ramp creek. On the hill to the north a well was sunk and this same rock was met at a depth of forty feet. This is at an elevation considerably above the top of the bank at the creek. Across in Page county there are outcrops on the slope several feet above the stream.

With one exception* the rocks here along the Page-Montgomery line represent the most southern known exposure of

*Proc. Iowa Acad. of Sci., vol. I, Part iv., pp. 33-43. 1894.

Cretaceous strata in Iowa. White placed the limit at Red Oak, but further investigation has resulted in finding the ferruginous pudding-stone, which in most instances marks the presence of the Cretaceous, south of Red Oak along the county road about one mile east of Essex.

Washington Township.—The only definitely recognized Cretaceous within this township lies near the center of section 21, just southward of the West Nodaway, perhaps thirty feet above low water. It consists of soft sand deposits with a vertical exposure of only seven feet. In color it is yellow to dark brown. Loose fragments of very dark siliceous limonite, such as overlies the measures elsewhere in the county are not uncommon.

Above the branch in section 27, Sw. qr., Sw. ¼, there is shown a few feet of yellowish clay which is very plastic and contains but very little impurity. This clay is in all probability of Cretaceous age.

Across the county line in Adams county limited exposures of Cretaceous are exhibited along the roadside between sections 19 and 20 also 16 and 17 in township 72, range XXXV. In these localities the measures are recognized by the slabs of hard, brown, iron-stained sandstone and lighter shades of the softer rock of unknown thickness. The uplands between the West and Middle Nodaway in at least northeastern Montgomery county and northwestern Adams are for the most part underlain by the Cretaceous rocks. Heretofore they were not recognized south of the small outliers in the south-central portion of Cass county.

Between the exposures mentioned in the vicinity of the East Nishnabotna in the western half of Montgomery county, and those between the two Nodaways in the extreme western section, the actual existence of rocks of the same age is not commonly shown by natural exposures. There is one exception. It is located about eighteen feet above a small stream in Tp. 73 N., R. XXXVI W., sec. 29, Sw. qr., Ne. ¼. Here grey and red sandy clay and sand with disseminated siliceous limonite fragments, are displayed in an imperfect outcrop. However, in the Rosacrantz prospect hole already mentioned, beds of

Cretaceous sandstone were penetrated, and combining this fact with the conditions on all sides it is safe to assert that the district between the Nodaways is underlain by a considerable thickness of Cretaceous. Above it is the rather heavy covering of drift; below it is the upper Carboniferous.

LITHOLOGICAL FEATURES.

Reviewing the descriptions just detailed it will be seen that the general character of the deposits varies greatly at different stratigraphic levels. Even at the same level the characteristics are not persistent for any great horizontal distance.

Arenaceous Deposits.—The only rock at all similar to the brown stone which has been quarried near Lewis, occurs as a covering from one to fourteen inches thick over the light-colored more friable sandstones. This mantle, however, is harder and more ferruginous than the quarry stone at Lewis. In some instances it changes gradually into the lower stone, but ordinarily the thin covering weathers free. For the most part the Cretaceous of Montgomery is an arenaceous formation. Near Red Oak and at Coburg the sand beds are heterogeneous, certain layers being more or less pebbly. Here current bedding is a prominent feature. At the "sand spring" just south of Red Oak, the twelve foot exposure bears near its central portion a layer two feet thick which is decidedly cross-bedded, while above and below, the lines of deposition are nearly horizontal. Towards Stennett the measures are much like the arenaceous deposits in the vicinity of Red Oak except that at Stennett the color is bright yellow to orange.

Conglomerate Materials.—From Red Oak southward to Coburg the most noticeable stone of Cretaceous age is the pudding-stone. Non-siliceous limonite is the cementing material. This conglomerate usually occurs in ledges from two to fifteen inches thick, and may or may not be false-bedded. At Coburg, also in the northwest quarter of section 17, two miles northward, this stone exhibits very marked cross-bedding, and under it lies the soft sandstone itself even more irregularly stratified.

Shale Beds.—The micaceous sandy shales which occur with very considerable thickness at the Keystone mill below the

county seat, are the only beds of such character yet recognized south of the principal Iowa Cretaceous at and near Sioux City.

For a number of years the argillaceous seams at Red Oak have been utilized in the manufacture of clay products. In character these shales vary somewhat from the smooth, homogeneous, very plastic—not gummy, to the more siliceous beds locally known as fire clay. In this latter case the siliceous material is not commonly disseminated throughout the stratified clay beds, but appears as partings separating the nearly pure argillaceous bands. The silica occurs as microscopic grains. The pure clay is by no means gritless, but in the production of common pottery the silica is in such minute grains as not to be injurious. Other imperfectly exposed Cretaceous clays occur at two or three points along the track north of Coburg. They do not possess the shaly character of the Red Oak clays nor are they so free from ferruginous and arenaceous matter.

Lenticular masses of clays such as occur in the clay bank at Red Oak, are found in smaller bodies disseminated through the soft sands in the banks of the stream in the northern edge of the town and in the southern part of Sherman township.

FLORA.

Remains of plants are very abundant in different beds of the Dakota at Sioux City and Sargent Bluff. Where best preserved the leaves lie in a dark red to brown ferruginous sandstone. Leaves have also been observed in the brown stone at Lewis. Reference has already been made to Meek's discovery of specimens of exogenous leaves in the sandstone at Red Oak. The beds in which these were discovered have not been worked for any purpose and no other record of the presence of vegetable remains has been made. The identity of the Cretaceous flora of Montgomery and Cass counties, with that of northwestern Iowa, and of Ellsworth county, Kansas, has already been suggested. From the very nature of the Dakota sandstone the complete preservation of delicate foliage could scarcely be expected.

FAUNA.

The Cretaceous formation of Montgomery county is marked by extravagant current-bedding characteristic of marginal deposits. Animal remains, if they occur at all, are likely to be found only in the finer argillaceous beds, but an examination of these beds at Red Oak has not resulted in the finding of any animal fossils whatever. In the pudding-stone formation near Coburg occasional fragments of coral, and now and then some other imperfect fossil species have been discovered. These, however, have no significance, since they were derived from the same source as the associated pebbles and have no relation to Cretaceous faunas.

TOTAL THICKNESS.

At the Milner well (Tp. 73 N., R. XXXVIII W., sec. 35, Ne. qr., Se. ¼) the Cretaceous was reached at 118 feet and extended to 223 feet beneath the surface. At that depth the measures were not completely passed through. Estimating the surface of the ground to be about two hundred feet above the bed of Pilot branch a short distance northward, it is evident that the coal measures would be reached but a few feet lower; making the vertical extent of the Cretaceous here about 115 feet.

Near Red Oak the total thickness is perhaps as great, but the beds are composed of different materials; sandstones, clays and micaceous sandy shales. Farther southward the contact of the Cretaceous with the underlying strata is not shown, but near Coburg and two miles northward the actually connected exposures are from thirty to sixty feet high. Beyond the top of the outcrops the hill rises to a considerable height. The extreme thickness at any selected locality may be placed at 125 feet and the total thickness of the measures within the county between 150 and 175 feet.

PLEISTOCENE.

The unconsolidated surface materials in Montgomery county are composed of the following: 1. Glacial deposits. 2. Loess. 3. Alluvium. These may all be included under Pleistocene.

LOWER TILL.

The true glacial deposits of the county are referred to the lower till. Although decidedly variable in character, this formation may be separated into two general divisions, blue boulder clay and yellow boulder clay. The former lies unconformably upon the stratified beds of the Cretaceous or upper Carboniferous and is not commonly exposed. It consists in the main, of a bluish grey clay. The upper part is a tough plastic variety, not very sandy yet bearing a percentage of both fine and coarse siliceous matter. It carries calcareous particles and concretions which vary in size from minute specks to irregular masses two or three inches across. The lower or more truly blue clay is homogeneous, and being siliceous lacks much of the plasticity common to that clay above it. Impurities such as lime are less abundant in the true blue clay. Exposures of this lower drift are by no means numerous. Occasionally, in excavations and in newly washed banks, a few feet of it are shown. The base of the lower till is made up of quicksand and fine gravels commonly free from argillaceous matter.

In the sinking or driving of shallow or surface wells, this purer clay is passed through and the underlying sand and gravel serve as the water-bearing strata. Water-worn boulders are distributed to some extent throughout the upper part of the blue till.

The common yellow drift clay overlies the blue division. It consists of a clay, yellow to green and brown in color, in which concretions of lime, pebbles and small boulders of siliceous rocks are freely disseminated. The texture of the yellow boulder clay is not unlike that of the lower blue clay except for the presence of pebbles and boulders. The boulders are mostly granites of varied hues. Schists, quartzite, diabase and other varieties of rock are not of uncommon occurrence.

Where but thinly covered the upper portion of the till has been modified by percolating waters until now the calcareous concretions have been dissolved and a partial or total disintegration of the contained granitic rocks has taken place. These altered deposits, besides being freed of much of their impurities

become thinner and distinctly jointed, which latter structure is more evident as the clay becomes completely dried.

In addition to the regular yellow boulder clay there are in the till limited deposits of coarse sand, in part argillaceous and completely iron-stained. Surface boulders are by no means common. There are a few points, however, especially in the northwestern portion of the county, where the surface shows pebbles and small boulders. Again, at intervals along the principal drainage courses boulders several feet across are seen. These have fallen from corraded banks. In character these rocks are not unlike those contained in the regular boulder clays.

The total vertical extent of the drift is not brought out except in deep borings, and from these the variation in thickness is found to be considerable. In the southwestern part of Douglas township the depth to the Carboniferous rocks, as shown in the Rosacrantz and McCracken deep drillings amounted respectively to ninety and one hundred feet. This latter thickness was entirely of Pleistocene and only the upper twenty feet of the Rosacrantz was of the unconsolidated beds. In the Davis well (Tp. 72 N., R. XXXIX W., sec. 8, Sw. qr., Sw. ¼) about three miles and a quarter northwest of Hawthorne, no stratified beds have been reached at 120 feet from the surface, and here all except the upper twenty feet consist of yellow and blue boulder clay, in part gravelly. It may be that in the highest points in Lincoln township the thickness of the drift mantle will prove to be in some cases more than 160 feet. In the edge of Cass county the boring of several wells proved the depth to the bottom of the till to range between 80 and 110 feet, with overlying loess usually not more than 15 feet.

In the central and southern tiers of townships the drift mantle has a thickness of from twenty to sixty feet. Where the coal measures occupy an unusally high position the covering is mainly of loess and is not more than ten feet thick. On the other hand a few localities in this portion of the county show drift extending to the surface. The irregular and unequal erosion of both the Carboniferous and Cretaceous beds has in turn left a corresponding roughness in the under surface

of the drift. This, together with the varying thicknesses due to its own irregular deposition has resulted in the variation in the thickness of the till which is now so noticeable.

LOESS.

For the greater part the entire upland of the county is covered with loess. The western boundary of Montgomery is approximately twenty-five miles east of the Missouri river, along which bluffs and knobs composed nearly entirely of loess rise to heights from 100 to 200 feet above the water level. However, this formation so heavy here, attenuates very rapidly eastward so that over Montgomery county its extreme thickness is perhaps thirty-five feet and its average scarcely more than four or five feet. Over limited areas there is a marked absence of true loess. In other rather broad stretches it is altered to such a degree that it is impossible definitely to place the line of contact with the under till. In character the formation is variable. The heavier deposits have lost some of the features which characterize typical loess. The color is nearly similar, but its texture has been so altered that instead of the massive, porous variety there is commonly a jointed more plastic clay. The homogeneity of any particular division is retained. Throughout the great loess bed of western Iowa and elsewhere hard lime concretions, known as loess-kindchen, are disseminated in patches at irregular intervals. If such ever existed in the deposit in Montgomery county they have been dissolved out by percolating waters. Loess shells, so abundant in the heavy beds, are not known to be present in Montgomery county.

ALLUVIUM.

Valleys with widths varying from a few yards to nearly two miles border the East Nishnabotna, the West and Middle Nodaway rivers, and the Middle Tarkio and Walnut creeks. These constitute the flood plain area of the county. The larger streams flow in the wider valleys. A distinction between the first and second bottoms has already been made. The former is more properly an alluvial deposit. Superficially it consists of a grey to black silty material which grades downward

into a mixture of siliceous clay and sands. The so-called second bottom extends from the most recent flood plains to the base of the hills. The upper fifteen inches are perceptibly colored by decayed vegetable matter.

The make-up of the lower portion of the second bottom is disclosed in dug wells and along the streams. Its constitution is not constant. Evidently the materials originated in part from the Cretaceous measures, severed and redeposited without any great breaking up of the mass and in part from a redeposition of the till and loess which has washed from the slopes. The thickness of the alluvial deposits varies somewhat with the irregularities in the surface upon which the washed materials were laid down. The upper surface is usually nearly smooth with slope sufficient for ample drainage. Next to some of the smaller water courses the alluvial fields are in disconnected patches first on one side then on the other side of the channel.

ECONOMIC PRODUCTS.

BUILDING STONES.

Notwithstanding the fact that exposures of hard rock in Montgomery county are quite rare and confined to certain comparatively limited fields, rock suitable for ordinary masonry is abundant. The quarry industry is one of no mean importance. The Upper Carboniferous, the Cretaceous and the Pleistocene are productive of rock for building purposes. In order of importance these beds are as follows: limestone, sandstone, conglomerate or pudding-stone and glacial boulders.

LIMESTONE.

Quarrying in the rocks of the Upper Carboniferous has been prosecuted here for more than a quarter of a century. The first work was done just north of what is now the town of Stennett. Since then other quarries have been opened in this vicinity on the west as well as on the east side of the Nishnabotna and the total amount of stone taken out and utilized has been great. The limestone occurs in ledges from a few inches to more than three feet thick. As a rule it is durable and

readily adapted to use in massive masonry and for all common purposes. Many of the beds are susceptible of a fine finish.

The W. Stennett quarry lies at the point of the hill near the Red Oak and Griswold line of the Chicago, Burlington & Quincy railroad, just above the mouth of Pilot branch. Layers nearly on a level with the waters of the East Nishnabotna, west of the track, have been developed.

The section on page 392 shows the workable and worthless beds, as well as the amount of stripping. At present this stripping would include all material above number 8 of the section, but as the work is pushed farther into the hill ledges of limestone now thoroughly weathered will become solid and of value. At the same time the thickness of the refuse material increases. The breadth of the quarry is not more than forty feet. A single derrick has been in use.

The C. B. & Q. Ry. quarry lies at the opposite side of Pilot branch and shows the same ledges of stone as those worked at the Stennett quarry. This quarry has not been worked for three or four years. Stone has been quarried at Crandall, about a mile and a half north of Stennett, and quarrying has also been done at a point the same distance south of the station. The upper ledges shown at the Stennett quarries were developed in both cases.

The Fate quarry is an old quarry situated on the west side of the river in the northeast corner of the southeast quarter of section 22, Sherman township. The face is nearly 100 feet in length. Until recently the full section as described on page 392 was opened and the numerous ledges utilized for various purposes. At the present time the three ledges shown are the only ones worked. The uppermost undivided ledge is twenty inches thick. It is finely sub-crystalline and slightly fossiliferous. The other two are also heavy ledges, the upper one being fourteen and the lower twenty-four inches thick. The stripping here, including the shale and impure rock between the beds, amounts to more than ten feet. The stone is all used for dimension work and takes a ready finish. One derrick is used in loading the stone.

The Rosebury quarry is on the south side of a small stream (Tp. 73 N., R. XXXVIII W., sec. 21, Se. qr., Se. ¼) and has a lineal face of about 120 feet. The following is the section:

		FEET.	INCHES.
9.	Soil, loess and drift	1	8
8.	Limestone, sub-crystalline, brittle; good dimension stone	2	1
7.	Shale, buff to grey	3	4
6.	Limestone, soft, flinty in upper three-fourths	1	4
5.	Limestone, sub-crystalline; foundation and dimension stone	7	
4.	Limestone bearing many specimens of Fusulinæ and much chert	4	
3.	Limestone with Fusulinæ and some calcite cavities	20	
2.	Limestone, yellow, earthy; crowded with Fusulinæ	5	
1.	Limestone, abounding in Fusulinæ and dark flint	2	2

The Ladd quarry is in the bluff west of the river (Tp. 73 N., R. XXXVIII W., sec. 27, Ne. qr., Sw. ¼). Work in this quarry has not been carried on since the season of 1892. The sequence of strata which includes the quarried ledges is here given:

		FEET.	INCHES.
6.	Decomposed limestone and clays	6	
5.	Limestone, abounding in Fusulinæ	1	10
4.	Limestone, same as No. 5, but also flinty		10
3.	Limestone, earthy; decomposed in part	3	6
2.	Limestone, blue; sub-crystalline: dimension rock		7
1.	Limestone, light grey, many Fusulinæ and light grey flint (exposed)	1	4

The H. Rush quarry is also on the west side of the river (Tp. 73 N., R. XXXVIII W., sec. 27, Ne. qr., Ne. ¼) a short distance northward from the Ladd quarry. Here several ledges were worked, the greater number of which can be found in Fate quarry. The beds presented are:

		FEET.	INCHES.
6.	Soil and loess	6	
5.	Limestone, hard, sub-crystalline; dimension stone	1	7
4.	Shale, argillaceous, buff to greenish	3	4
3.	Limestone, impure ocherous	1	2
2.	Limestone, semi-crystalline, light colored; dimension stone	1	
1.	Limestone, hard, light color; dimension stone	2	

The S. Stennett quarry is one recently opened on the east slope of the hill (Tp. 73 N., R. XXXVIII W., sec. 22, Se. qr., Se. ¼) perhaps thirty feet above the river. Thus far only the three principal ledges of the Fate quarry, as now worked, have been developed. A considerable quantity of stone has been removed from the same ledges in other small quarries in sections 22 and 27.

The new Clark quarry is situated about a mile west of the East Nishnabotna (Tp. 73 N., R. XXXVIII W., sec. 33, Se. qr., Nw. ¼). The face of this quarry as now developed is about 150 feet long. The following shows the sequence of strata:

		FEET.	INCHES.
11.	Soil and geest with weathered limestone slabs and flint	4	
10.	Limestone, much black flint present		5
9.	Limestone, abounding in part with Fusulinæ	1	
8.	Limestone, two ledges with Fusulinæ and light colored chert	1	8
7.	Limestone, earthy and fossiliferous	2	4
6.	Limestone, hard, grey; dimension stone		7
5.	Limestone, flinty		6
2.	Limestone, buff colored; of more or less earthy texture		6
3.	Limestone, buff to light brown, somewhat shaly	5	
2.	Shale	1	1
1.	Limestone, hard, greyish, with dark flint; Fusulinæ throughout ledge	1	5

The abandoned Clark quarry lies about a quarter of a mile northward. The dip, if any, is imperceptible.

The McCalla quarry (Tp. 73 N., R. XXXVIII W., sec. 33, Sw. qr., Se. ¼) lies about a quarter of a mile southwest of the new Clark quarry. It is crescent shaped, quarrying being done on either side of a shallow ravine. The thickness of the waste material is not great, and several ledges of stone are available; as shown in the accompanying section:

		FEET.	INCHES.
13.	Soil	1	
12.	Limestone, decomposed, Fusulinæ bearing	1	6
11.	Clay, for the most part residual	1	4

		Feet.	Inches.
10.	Limestone, hard, light to dark grey		7
9.	Limestone, with black flint, hard in central part; many Fusulinæ present throughout	6	
8.	Limestone, buff to brown in color, Fusulinæ irrregularly distributed	1	
7.	Limestone, light, twelve-inch ledges; (weathered)	1	8
6.	Unexposed, probably similar to number 9	4	
5.	Limestone, thin layers, shaly partings	5	2
4.	Limestone, hard, greyish brown; concretions of dark flint disseminated in central portion	1	5
3.	Limestone, earthy		8
2.	Shaly parting		2
1.	Limestone, buff, earthy	1	

Further development will doubtless result in bringing to light workable ledges in numbers 5 and 6. The divisions are now badly weathered.

The Silket quarry is on Walnut creek in Tp. 72 N., R. XXXIX W., sec. 1, Ne. qr., N. $\frac{1}{3}$. At this point the most important beds lie in the bed of the creek. The combined section is:

		Feet.	Inches.
6.	Soil and residual material	5	
5.	Shale, buff to grey		8
4.	Limestone (decomposed) and shales	5	
3.	Limestones, flint-bearing	1	2
2.	Limestone, hard, greyish, in two ledges; dimension stone, very fossiliferous	1	5
1.	Limestone, "blue layer," dimension stone	1	4

A short distance from this opening on the low slope on the east side of Walnut creek several ledges of limestone have been worked.

The next quarry along Walnut Creek is at Climax (Tp. 71 N., R. XXXIX W., sec. 30, Ne. qr.) At this point the following section was secured:

		Feet.
7.	Soil, loess and drift	18
6.	Limestone, hard, drab, finely textured; not fully exposed	1
5.	Limestone and shale, marly	3
4.	Shale, argillaceous, grey	2
3.	Limestone, bluish, dull, earthy	1
2.	Shale, argillaceous, grey	1
1.	Limestone, light blue, hard; dimension stone	1½

Since the covering is heavy it is not probable that quarrying, other than for local use, will at any time be done here. Up to this time no large amount of stone has been removed.

The supply of building stone in the southern portion of the county is obtained partly in Montgomery county and partly in Page. There are three or four quarries in the latter county within a distance of a few miles from the south line of Montgomery. The Gridley quarry is just across the line. The Nelson limestone quarry (Tp. 71 N., R. XXXVII W., sec. 20, Nw. qr., Ne. ¼) lies in the bed of a small tributary of Middle Tarkio. It has been opened but a year or two, and since that time has been worked to supply the local demand and the demand at Stanton.

But two ledges of stone are utilized. The lower one is a foot thick. It is a hard, greyish blue limestone bearing disseminated particles of iron pyrites often changed to the hydrous oxide. On account of this impurity the stone would be slightly inferior for outside walls. Between this bed and the upper bed there are about six inches of marly shale. The top ledge—a yellowish grey, more or less earthy limestone, is also one foot thick. The output from this quarry is used largely as foundations, and as undressed dimension stone.

The abandoned Johnson quarry is in the N. ½, Sw. qr., sec. 20, Tp. 71 N., R. XXXVII W. On the other side of the branch, and southward a few hundred feet, is the old Jacobson quarry. Across the Tarkio near the southeast corner of section 20, is the deserted Lantz quarry. The stone at all of these places is but the continuation of the strata at the Nelson quarry.

Northward, about half way between the Lantz quarry and Stanton, a few perch of stone are annually taken from the slope some distance above Middle Tarkio. East of Villisca, about a mile and a half, limestone has been obtained and used for flagging and for cellar walls. This quarry is on a small branch near the main line of the Chicago, Burlington & Quincy railroad. There being but one bed of particular value and it covered by several feet of clay shale, but a small amount of work has ever been done to open up the quarry.

The northeastern township is well supplied with a superior building stone, but located as the quarries are, ten miles or more from any railroad, the annual output from this section of the county is comparatively small. Only a local demand can be economically met.

The Smith quarry is in Ne. ¼, Sw. qr., sec. 3, Tp. 73 N., R. XXXVI W., extending non-continuously for a distance of perhaps 600 feet along the west hillside. At the north end the following section was secured:

		FEET.	INCHES.
4.	Soil, loess and residuary clay	3	10
3.	Limestone, weathered, with geest in crevices	5	
2.	Limestone, light grey, sub-crystalline, flinty	1	8
1.	Limestone	1	

Toward the southern part the worked face of the section is somewhat different. Across the West Nodaway, possibly 100 yards west of the Smith quarry, is the one known as the Fisher. The following beds are exposed:

		FEET.	INCHES.
4.	Soil and loess	5	
3.	Limestone, shaly	1	
2.	Clay, shale, grey to yellow	2	6
1.	Limestone, flinty in upper part, bear Fusulina (solid ledge exposed)	3	3

The stone in the vicinity of Milford is commonly a rather coarsely textured variety, hard but easily dressed. In color the light greyish-brown prevails. Between the two quarries mentioned and the milldam at Milford, where much stone has been taken out, there is another exposure of limestone, presenting three layers. Each is about two feet thick, and over the beds are nearly twelve feet of stripping. This place, and the Smith and the Fisher quarries, have furnished a great amount of stone for dimension work, for buildings and for the construction of the Milford dam. It is a very tough, durable stone which does not fracture in cold weather, nor shell off upon continued exposure.

In the edge of Cass, at the very extreme northeast corner of Montgomery county, there are two rather extensive quarries,

the Phelps and the Fox, respectively on the west and east sides of the county road. The strata exposed at the one is also shown at the other, except that the Fox has been worked to a greater depth. Only those above number 5 in the section here inserted are disclosed in the Phelps. The individual layers are as follows:

		FEET.	INCHES.
13.	Soil, limestone slabs and residual clay	2	
12.	Shale, argillaceous, greenish	4	
11.	Limestone, light colored (one ledge)	2	6
10.	Limestone, light grey to buff	1	1
9.	Clay, marly	1	
8.	Limestone, sub-crystalline, greyish to brown ledges from nine to fourteen inches	7	1
7.	Shale		4
6.	Limestone, brownish, sub-crystalline to dull	1	2
5.	Shale, bituminous in lower portion	1	6
4.	Limestone, coarsely textured		9
3.	Shale, buff to grey; fossiliferous	1	4
2.	Shale, variegated, carbonaceous near bottom	2	1
1.	Limestone (exposed)	1	

These quarries are so situated as to supply stone for Adams, Cass and Montgomery counties. A number of the ledges are successfully used in heavy masonry; blocks of almost any desired dimension can be obtained. The stone is not difficult to dress. It is certainly unfortunate that better transportation facilities from such quarries as these in Montgomery and across the line in Cass are not at hand.

In addition to the quarries already mentioned, there are a number of places where limestone has been taken out. On account of the great depth of stripping and the inaccessibility of the ledges, work was but temporary. The ravine south of Red Oak below the Keystone mill, at Clark mill, a quarter of a mile southeast of Coburg, southward from Hawthorne in the bed of Walnut creek, and in the edge of Page county (Tp. 70 N., R. XXXVIII W., sec. 4) are the more common localities. In most cases but one or two ledges are accessible.

SANDSTONE.

Within the limits of the county the coal measure sandrock is entirely absent. The only arenaceous beds which might

serve as structural material belong to the Cretaceous, representing the Nishnabotna sandstone. About Red Oak near Stennett, also in the southeast quarter of section 35 of Sherman township, the northeast quarter of section 2 of Red Oak township, there is a dark to light brown sandrock from two inches to more than three feet thick overlying the friable, light colored stone. It is hard enough in many places to serve for foundation and rough construction work. In part this stone is not unlike that at the quarries southwest of Lewis, Cass county, where a large amount has been removed and utilized for the erection of houses, foundations and chimneys. Only occasionally has any of this stone been quarried in Montgomery, the thickness being usually insufficient and the color of the stone undesirable.

CONGLOMERATES.

The Cretaceous pudding-stone occurs on the steep slopes east of the river, almost continuously from three miles south of Red Oak to within three-fourths of a mile north of the southern boundary of the county. The maximum thickness of the bed is not definitely shown but the average is approximately twenty-five feet.

The Chicago, Burlington & Quincy railroad company has opened up the Cretaceous conglomerates in the east half of the northwest quarter of section 17, Grant township, and has quarried a great amount of the material for ballast. Here the beds are firmly cemented by siliceous limonite, but in the lower portion they are of loose pebbles and coarse sand. No work has been done in this place in the last few years. Just east of Coburg the lower portion of this conglomerate is exposed and the layers have been used to a small extent for foundations. A few hundred feet up the small branch from the southeast corner of Red Oak there is another bed of loose pebbles in coarse sand which might be used advantageously as ballast.

GLACIAL BOULDERS.

Being generally concealed by the loess, the drift debris furnishes but an inappreciable quantity of available rock which would be at all suitable for dimension stone. In the southern half of the county there is seen an occasional boulder several

feet across. In the northern part there are patches of uncovered glacial deposits which afford material valuable as rough foundation stone.

CLAYS AND THEIR USES.

The quality and the very general distribution of clays suitable for the manufacture of various grades of building bricks and for drain tile, make this material of primary economic importance in Montgomery county. Throughout the district, with only a few exceptions, it is possible to find superficial deposits having depths of from two to twenty feet, of such constituency as to be readily worked into marketable products. In order of importance on account of adaptability and prevalence the clays may be classed as follows: (1) Loess; (2) Cretaceous shales; (3) Alluvium; (4) Coal measure shales; (5) Boulder clay.

LOESS.

The loess is quite generally distributed. It occurs as the mantle of the upland over nearly the entire area. In thickness it is variable, and in character it may be divided into the two more common forms—that found on the slopes and well-drained sections, and that on the level prairie. The former is a brownish-colored, homogeneous material resembling in great part the deposit where typical along the Missouri bluffs to the west, bearing hard, calcareous concretions. The prairie loess is of a greyish yellow to brownish color, decidedly more plastic than the other and containing no detrimental impurities. These clays are such that good brick or tile can be manufactured from either, but on account of the excessively elastic or "stronger" nature of the prairie deposit, much trouble will be experienced in attempts to avoid cracking while the brick, especially, are being dried. A combination of the two varieties or the introduction of shale clay or sharp sand into this strong loess will largely lessen the amount of checking.

Methods for handling these clays depend primarily of course upon their nature, but almost any of the deposits can be moulded by hand, by the wet-mud, by the stiff-mud or by the dry-press processes. In this county the use of the loess alone

has been attempted at but one factory and the two last named methods are practiced. At some of the larger factories, however, very successful results are obtained by combining the loess in various proportions with the clays of the Cretaceous. Regardless of the kind of process the treatment to which these clays are subjected is the most simple and the products are successful and durable, invariably possessing a desirable color.

CRETACEOUS SHALES.

While not occurring abundantly in more than one or two localities Cretaceous shales are of such a character as to be adaptable to use in clay plants in the manufacture of many kinds of products. Under the description of the lithological character of the Cretaceous, mention has been made of the several localities supplied with argillaceous materials of that age, so but a brief reference to these will be inserted. Of the clay under the soft sandstone (Tp. 72 N., R. XXXVIII W., sec. 2, Ne. qr.) White* says: "A bed of clay is found which is a mixture of a dark and ochery clay with that of nearly white color. The latter has been tested for the manufacture of common pottery and pronounced to be the best found in the southwestern part of the state." The only clay of such description now exposed in this neighborhood lies in pockets or lenticular beds, and in quantities too small to be of any value.

Along the railroad track, about two miles northward from Coburg, beds of grey and of red arenaceous clays are visible. These might be utilized if not overlain by such heavy stripping. The beds at Red Oak are by far the most important. They are extensive, conveniently situated, and are quite pure. The presence of clay in this neighborhood was ascertained through outcroppings well toward the top of the hill above the present pit. The raw material was first secured from numerous pockets which were found to contain very limited amounts of a first class clay, and soon the supply became exhausted. Careful prospecting, however, led to the discovery of a large deposit, the upper surface of which extends almost as high as the railroad track to the south. The shale shows the effects of erosion,

*First and Second Ann. Rept. of the State Geologist, p. 64. 1868.

deep gorges having been corraded, and the uppermost portion being mixed with a reddish loess. Eastward the clays are intermingled with arenaceous blocks and masses of siliceous limonite. The adaptabilities of this shale in its purest state are hardly limited. It has been made into common stock and fire brick, sidewalk blocks, drain tile and pottery. It is easily prepared. Brick are successfully made by the dry-press or by the stiff-mud machine. Ordinarily the shale burns to a cream color, but when combined with ferruginous clay different shades of red are secured.

ALLUVIUM.

The alluvial deposits of the county occur only along the larger water courses. The upper two or three feet only are available, unless a special treatment is given, and this is hardly practicable. In the immediate vicinity of the rivers traversing the county the alluvial deposits are of a loamy character for a depth of several feet, and in this case the entire thickness of the material can be made into common brick, using the hand presses for moulding.

COAL MEASURE SHALES.

Unlike the lower, or Des Moines stage, the upper coal measures, or Missouri stage, does not present many heavy beds of argillaceous shales. Yet between the solid ledges of limestone in various sections of Montgomery county there exist layers of good workable shales from two to eight feet in thickness. Around Stennett the quarries exhibit such beds, one of the most noticeable being shown resting on the top ledge of limestone in plate xi. Along the branch, about a mile and a half east of Villisca, a similar bed is visible. South of Red Oak the exposures are imperfect. Recent excavations disclose several shale beds at Villisca, some of which are quite valuable. Others bear calcareous fossils and are not so successfully utilized.

On the cap-rock over the coal vein which occurs in the northeastern portion of the county there rests a shale several feet thick, and under the coal is an impure fire clay, two or three feet thick, which changes to ordinary shale lower down.

These beds do not appear exposed at convenient points, but since the vein of coal averages only about eighteen inches it is necessary to remove a portion of either the under or the overlying strata. These accompanying argillaceous materials are suitable for draintile, paving and common brick, and also, in some cases, for sewer-pipe and fire brick. The establishment of clay plants in connection with the coal mines could be made profitable. In some localities in the state this plan is followed very successfully, even where the removal of the shale is not necessary in order to mine the coal. As yet no attempts have been made to extensively utilize the shales of southwestern Iowa. Experiments have been carried far enough to demonstrate their utility.

BOULDER CLAY.

The drift although bearing extensive argillaceous beds, is neither a convenient nor a profitable source of workable clays, partly on account of the overlying deposit of loess and partly on account of the concretions of lime which abound in the upper, or yellow, boulder clay. These concretions are very injurious to the burned product. It may be possible to find limited areas of altered drift which have been freed from this impurity by percolating water.

PAINT AND BALLAST CLAYS.

About a quarter of a century ago a plant was established for the production of mineral paint from an ocherous shale, and a considerable quantity was marketed. The expense incurred in preparing, and in transporting the product to shipping points made the undertaking unprofitable, and work ceased. The bank is now entirely covered by over washed soil. At Milford in the sinking of a well, the occurrence of an eight-foot bed of ocher was reported at forty feet from the surface. In all likelinood this is an ordinary vari-colored coal measure shale, and is not valuable as a base for paint.

In the construction of railroads the use of burnt clay as ballast is fast becoming popular. In the altered loess and drift, and in the more gumbo-like areas of the bottoms, material might be selected suitable for the manufacture of this

product. Ballast burning was carried on for some time at Red Oak nearly fifteen years ago, and much of the burnt clay was used along the line of the Chicago, Burlington & Quincy railroad.

CLAY INDUSTRIES.

Three of the principal towns of Montgomery county are supplied with plants utilizing native clay in the production of structural brick, drain tile and other articles.

RED OAK.

The W. H. Close Pottery, Brick and Tile Works is located near the central portion of Red Oak. The nucleus of this concern was formed more than twenty years ago, but until 1883 attention was devoted entirely to the manufacture of pottery. Included in the list of articles now produced are front or stock brick, common brick, fire brick, sidewalk blocks, draintile from two and a half to eight inches in diameter, and all styles and sizes of ware commonly made at modern potteries. The plant consists of necessary sheds, including those for drying the green ware a Bond dry-press, "The Ohio" of E. M. Freese & Company a Wolfe & Conley continuous, and six common down draft kilns, two being used in burning the pottery, a Frost dry pan and a clay chaser. Until so extensively enlarged two years ago only a Penfield plunger and the turning wheels with the chaser now used, made up the list of machinery.

The clay is all hauled about half a mile from down near the railroad track. That used for fire brick and pottery is of Cretaceous age. The more siliceous, when properly burned, produces a good refractory article. For tile, common, stock brick, and sidewalk blocks, either loess alone, or loess combined with the more impure Cretaceous shale is found most satisfactory. The admixture of the shale is productive of a lighter colored article, depending of course upon the relative amounts of shale and the strong dark brown to nearly red loess, which itself burns to a cherry red color.

The appearance of the cut while partially hidden by debris is shown in figure 54. The shale at some points is as much as fifteen feet thick and rests unconformably upon a very siliceous

shale of the same age. At the east end it is replaced by friable sandstones, and higher up, perhaps three or four feet above the upper surface of the shale, yellowish sandstone is shown in the

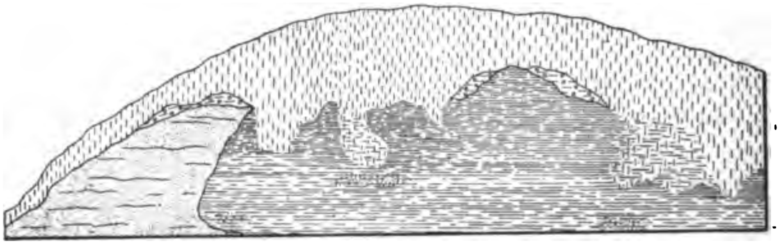


Figure 54. Cross-section of the Close clay pit, Red Oak.

railroad cut. The extreme thickness of workable shale in the portion of the clay bed at present developed is given in the following section; number 11 showing the average thickness of the overlying loess:

		FEET.	INCHES.
11.	Loess, impure in lower portion	6	6
10.	Sandstone, light yellow, soft	3	
9.	Shale, light grey; used for pottery		11
8.	Sandstone, white to yellow	1	6
7.	Shale, light grey; for pottery	2	
6.	Shale, grey, siliceous; for fire brick	1	1
5.	Shale, dark to light grey; for pottery	1	6
4.	Shale, grey, siliceous; for fire brick		2
3.	Shale, light to dark grey; for pottery	2	2
2.	Shale, greyish; for fire brick		6
1.	Shale, siliceous, grey, impure, exposed		6

The individual layers of the purest clays, those made into pottery, are constant throughout in texture and composition. The accompanying chemical analysis, made by Prof. G. E. Patrick, best shows the nature of the deposit.

	PER CENT.
Hygroscopic water (expelled at 100° C.)	1.33
Conbined water (expelled by ignition)	3.85
Silica (SiO_2)	69.75
Alumina (Al_2O_3)	18.68
*Iron oxides, calculated as Fe_2O_3	1.94
Lime (CaO)	1.07

*Mostly protoxides; an approximate determination gave: FeO, 1.22; Fe_2O_3, .58. This gives a summation of 100.89; error in analysis, .39.

	PER CENT.
Magnesia (MgO)	.95
Potash (K_2O)	2.32
Soda (Na_2O)	.64
Total	100 53

It will be noticed that the percentages are not perceptibly different from clays used at many Ohio, Kentucky, Indiana and other factories, the alumina being comparatively a little less. The clay is of such a character that, when moulded by the dry-press, burning must be accomplished with much care until the water has been entirely removed. To burn every section in the continuous kiln at one time from three to five weeks are previously consumed in water-smoking. This kiln has a capacity of 500,000 brick.

The fire brick are moulded on the Boyd press. They require a high heat to prevent crumbling. It is quite probable that this clay when washed could be made into a superior quality of glass pots and crucibles. In burning the pottery a very high heat is withstood before the slightest "crippling" takes place.

The raw material was at first taken from small pockets well up the slope from the track, but as these became exhausted search for new beds was necessary and this resulted in the finding of the bank now worked which to all appearances is inexhaustible.

The R. E. Cook brickyard is situated just north of the Chicago, Burlington & Quincy railroad at the southeastern corner of Red Oak. Work was begun here several years ago and has since been carried on quite satisfactorily. The equipment consists of an H. Brewer roller crusher, a Kells & Sons brick and tile machine, dry sheds, two clamp and one common round down draft kilns.

The clay is obtained from two adjoining cuts at the side of the plant. The upper one is circular with perhaps 200 feet of lineal face. The material here consists of twelve feet of ordinary loess. This rests upon three or four feet made up of mixed Cretaceous clays, boulder clay and loess. At the other pit the following sequence is seen:

		FEET.
5.	Soil and loess	3
4.	Clay, brown, pebbly	1
3.	Clay, greyish, rather gritty	4
2.	Shale, light grey, bearing sandstone lenses	2½
1.	Sandstone, white to dark yellow with argillaceous concretions	4½

The layers as indicated in the section are by no means persistent in different portions of the worked cut. From the drillings of a well bored here it is observed that shales with interstratified sandstone layers extend to some depth.

Although made up of a rather complicated variety of clays some of them decidedly impure and siliceous, the product, common building brick, is in no wise inferior. The brick have a good color and the mode of manufacture is entirely efficient.

VILLISCA.

Stoddard Brothers brickyard, operated by Smith & Coffin, is in the southern portion of Villisca. Here brickmaking has been carried on for ten years, always by hand until 1894, when a secondhand Frey-Sheckler stiff-mud machine was put in. The clay up to that time was a "bottom" clay from along the Middle Nodaway. Its thickness was from six to ten feet. The upper part is silty. That below the clay worked appears to be almost wholly derived from the loess, and portions of the material are somewhat jointed. Since the machinery was put in loess has been used. The quality of the clay is quite good, but the brick when drying crack badly in the sheds.

Recently a coal measure shale has been discovered which can be mined advantageously with the loess, and the cracking is thereby lessened. The beds now shown above the water are:

		FEET.
5.	Loess, yellow to brown or grey, jointed in upper part	12
4.	Sand, clean; thickness varies from one inch to	2
3.	Shale, argillaceous, dark grey to green in color	4
2.	Shale, argillaceous, light grey	3
1.	Shale, grey to light, rather finely siliceous	

Number 5 is a fine grade of clean loess strictly adaptable to use in the dry-press. Number 3 is quite pure and of good

quality, although the shrinkage upon burning will be considerable. Number 2 is for the most part a superior shale but is very fossiliferous, bearing both thin shells and crinoid stems, which latter are wholly calcite and become caustic when burned in the clay; otherwise this layer would be valuable for common uses. Number 1 is not fully exposed, but borings in the neighborhood are said to show it to be from twenty to sixty feet thick. Except for its being a little too arenaceous it is readily available for many purposes. It is now possible to utilize the loess and some of these shales and secure a superior building brick. The manufacture of pavers from the shales would be practicable but for the presence of the deleterious crinoid stems.

The Tyler brickyard is in the southern part of Villisca and east of the Middle Nodaway. It has been in operation five years. It is a small plant, the equipment consisting of a Quaker soft-mud machine, horse power. The clay bank is five or six feet deep and consists in the upper portion of a siliceous silt bearing a considerable percentage of humus. This grades into a brownish arenaceous clay locally known as "made earth." At the base of the cut joint clay sets in, and eighteen feet from the surface a bed of quicksand is encountered. Temporary kilns, holding from 80,000 to 135,000 brick, are used in burning. Some trouble is experienced in the cracking of the green product.

STANTON.

Nelson Sandin has a brickyard in the western part of Stanton along the banks of Middle Tarkio. The clay is a loamy material taken from the flood plain. Its thickness is variable, In some portions the so-called joint clay extends to within one or two feet of the surface. Ordinarily, however, it is possible to use the material to a depth of seven feet. It is found that, by the addition of common salt to the extent of six quarts to mud enough for 5,000 brick, the amount of checking during the drying process is greatly reduced. Cased kilns are used in burning. The consumption of the product is almost wholly local. The brick are rather porous and are therefore only used for interior construction work.

SAND.

Although containing little or no free sand in the beds and overflowed banks of the large streams, Montgomery county is well supplied with arenaceous deposits. They occur both in the Cretaceous and in the till. Those of the former abound wherever the formation exists. Near Red Oak and southward as far as Coburg, the prevailing color is nearly white. Near Stennett and to the east the sands are orange to yellow. The sandstone is fine grained except for a small percentage of coarse material in individual layers. The grains are more or less rounded but not so much so as in the drift sands. On account of the size and comparative sharpness of the grains the material is suitable for mason work and for use in brick moulds. The slight percentage of oxide of iron which it contains prevents its use in the manufacture of glass. However, it may possibly be utilized in moulds at smelters.

South of Milford (Tp. 73 N., R. XXXVI W., sec. 22, Sw. qr., W. ½) there is a high knob capped by loose sand and resembling an ordinary river deposit. For the most part the sand is quite clean and somewhat sharp. Its thickness is probably not less than fifty feet. Another deposit of similar character lies on the slope about one mile eastward from Villisca. This and the one near Milford are used by plasterers. The Villisca material is also used by the brick manufacturers to sand the moulds. Other localities furnish sand beds of economic value.

COAL.

Westrope Slope.—Since 1881 no mining of coal within the limits of Montgomery county has been undertaken. For several preceding winters, even as far back as 1857, mining was quite extensively carried on at the Westrope slope (Tp. 73 N., R. XXXVI W. sec. 1, Se. qr., W. ½). The vein was found outcropping several feet above Williams branch. Its thickness was from eighteen to twenty-two inches. The sequence of beds is shown in figure 48, page 403.

Anderson Prospect Shaft.—Coal was reported at a depth of fifty-five feet in a drilled hole (Tp. 72 N., R. XXXVI W., sec. 33, Ne. qr., Se. ¼) four and one-half miles north of Villisca. The

seam was said to be twenty-two inches thick. A shaft sunk with a view to mining the coal failed to reveal the presence of the stratum, and further search has not since taken place. It is not improbable that the Nodaway vein would be found at no great depth in this vicinity, though it may have been cut out by erosion.

A well just south of the Westrope slope disclosed the presence of the Nodaway coal, and just east of the boundary of Montgomery county (Tp. 73 N., R. XXXV W., sec. 18, Sw. qr.) it was again met with in digging a well. The record given below is said to be accurate:

	FEET.
7. Soil and loess	3
6. Shale, argillaceous	8
5. Limestone	4
4. Shale, marly	3
3. Sandstone	$1\frac{1}{2}$
2. Coal	$1\frac{1}{4}$
1. Fire clay	$\frac{1}{2}$

The coal mentioned in the different localities is the same vein as is worked so successfully at Briscoe, Carbon and Eureka in Adams county, at New Market and along the East Nodaway six miles northward, in Taylor county, southeast of Clarinda, near Shambaugh, in Page county. Along Middle Tarkio, southeast of Nyman, there has been a small development. Reference has been made to the extent of the vein. It seems to underlie, within available distances, nearly the entire northeastern third of Montgomery county, excepting perhaps certain localities in which erosion has been exceptionally deep. The indications are that westward the coal vein dips to too great depths to be of value. When coal was first removed from the Westrope slope the price was fifteen cents per bushel. Now it is usually from three to five cents less, though still great enough to make the mining of the vein profitable when near enough the surface. Facts brought out by the deep drilling and by a study of the exposed formations of Montgomery and adjoining counties, inevitably lead to the conclusion that only thinner seams such as already have been met with need be looked for. This conclusion is opposed to that heretofore

entertained, namely, that the lower measures would, when reached in southwestern Iowa, be equally as productive as in the central and southeastern portions of the state where the Des Moines division is exposed at the surface.

LIME.

The manufacture of lime in this district has never been undertaken except on a very small scale. Where the limestones are more abundantly exposed about Stennett and at Milford, as well as in the southern portion of the county along the Tarkio, a very fine quality of lime might be produced. The better ledges of the stone bear but a low percentage of silica or alkalies, the more common constituents which detract from the value of lime. The stone would produce a white lime, but one which would only be used for ordinary mortar or plaster, not being strong enough and being too readily affected by moisture for the better class of work.

ROAD MATERIALS.

The native substances which might be used advantageously for road beds are: limestones, clays, drift boulders, gravels and sands. As yet neither the streets of the larger towns nor the roads of the interior have been paved. The limestone, being as a rule hard, would make an excellent macadam. It would also serve as a basis for brick paving and as ballast for railroad beds. Mention has already been made to the use of burnt clay as ballast, and its use might be extended to the construction of county roads. Being comparatively inexpensive it will doubtless yet be used in districts not abundantly supplied with gravel. The preparation of the clay is very simple. In the upper portion of the Cretaceous, between Coburg and Red Oak, the conglomerates and loose sandy and pebbly layers are quite accessible and could be made available. The drift deposits, which are made up for the most part of coarse sand and large pebbles, when not overlain by clays, might also be used for similar purposes.

SOIL.

Within Montgomery county three distinct varieties of soil are present. These are the loessal, the alluvial and the glacial. The area bearing the first named is by far the greatest

as practically the entire upland prairie and the hillsides are covered by it. The soil proper, that is the dark grey colored, humus-bearing material, is commonly only a foot or two in thickness, but the loess from which this soil is directly derived has a thickness in some instances of as much as thirty feet. In character this loess, which acts as subsoil, is soft, more or less spongy and calcareous; it admits of easy infiltration of water in excessively wet weather. In case of drouths it readily gives up moisture by capillary attraction and furnishes a lasting supply to the growing crops. When altered the subsoil is more plastic and clay-like. This loess soil is the most productive variety within this part of Iowa.

True alluvial soils are naturally confined to the flood plains. The second bottom is not subject to overflows and the soil is more compact than that of the lower lands. These soils are all very siliceous and bear a considerable percentage of decayed vegatation in the upper portion, becoming more clayey below. Under ordinary circumstances they are remarkably fertile. The till where occupying the superior position in a few very limited areas, mostly in the northwest quarter of the county, could not properly be termed arable. It consists in the main of boulders a few inches in diameter and of sandy clay. There are also a few patches of Cretaceous land north of Coburg, which are of little or no value from a productive standpoint.

MINERALS.

Calcite, pyrite, limonite, hæmatite, and perhaps other rarer minerals occur in Montgomery county, but none in quantity sufficient to make them of economic importance. The calcite occurs in the form of crystals lining cavities in some of the ledges of limestone near Milford, and more rarely elsewhere. Pyrite is observed in the stone of the Nelson quarry and in the coal. Limonite occurs in the Cretaceous, but is very siliceous. A few hæmatite boulders were discovered in the surface drift.

WATER SUPPLY AND WATER POWERS.

The inhabitants of Montgomery county secure their water supply from several sources. The streams form the most

important one. The two larger water courses which traverse the entire length of the county and the Middle Nodaway in the southeastern portion, are never failing sources. The Tarkio, Walnut and Indian creeks are streams which in ordinary seasons are not dry, except well toward their sources. The drift deposit affords much water, and in this formation there are many veins which are practically inexhaustible. The water commonly lies in a series of pockets of sand or gravel between the yellow and blue boulder clay. These sand pockets are not persistent, nor is water invariably secured at this horizon, but failures are exceptional. In the flood plains it is nearly always practicable to go down from twenty to fifty feet, or a little below the level of the water in the stream, and strike a lasting supply. Red Oak and Villisca obtain their water supply from wells dug in the flood plains of the adjacent rivers.

Springs issuing from the upper coal measures have not been seen in the county, neither do borings in the strata, unless at great depths, show the presence of flowing veins. At the foot of the Cretaceous sands, probably flowing over shales, fine springs which never run dry pour forth large volumes of clear cold water. Notable instances of these are in Tp. 71 N., R. XXXVIII W., sec. 17, Nw. qr., E. ½, north of Coburg, at "sand springs" just south of Red Oak, in the northern portion of section 33, also in Tp. 73 N., R. XXXVIII W., sec. 13, Sw. qr., Sw. ¼ on the old Powell farm.

The rivers which act as unfailing water supplies may also furnish power. Ordinarily the declivity is not great but is sufficient to produce considerable fall. By the proper construction of dams power for various manufacturing purposes may easily be developed. Good locations are frequent as the channels proper are usually rather narrow and are bounded on one side or the other by a bank of limestone.

Along the Nishnabotna there are three mills utilizing water power; a grist mill a mile north of Stennett, Clark & Company's mill in Tp. 72 N., R. XXXVIII W., sec. 8, Se. cor. and the Keystone mill just south of Red Oak (Tp. 72 N., R. XXXVIII W., sec. 32, Sw. qr., Ne. ¼). At each of these points the river flows against stratified beds.

On West Nodaway there are the Smith mill at Milford, or Grant P. O., the Morton in the southern portion of section 33, Douglas township, and the Arlington in Tp. 72 N., R. XXXVI W., sec. 28, Nw. qr., Se. ¼. On Middle Nodaway, near the center of section 11 of Jackson township, is located the J. Van Horn mill. At Climax in the extreme southeastern part of the county a mill was once established. This was dependent upon the water of Walnut creek for power. It was found that the stream became too low in dry weather and milling at this point has been abandoned.

to Postville, 88. Peter, 71.

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